School Science

VOL. III] OCTOBER, 1903. [No. 4

THE PUPIL BEFORE AND AFTER TAKING CHEMISTRY.*

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I think that those of us who have been concerned in the preparation of descriptions of an ideal course in secondary school chemistry, or who have examined such descriptions, must have reached the conclusion that something better in this line is demanded and might be produced. As chairman of the Committee of the Natural Science Section of the National Educational Association, which prepared the syllabus of chemistry, I have since come to feel that the report which we presented was in many respects lacking in effectiveness. A large part of the syllabus was taken up by a list of topics which should be studied. Now, it is useless to suggest that the teacher of chemistry deal with the element hydrogen or the compound water, for it is inevitable that he shall do so whether we suggest it or not. There is no book on elementary chemistry which does not, as a matter of course, handle more or less fully all the topics mentioned in that report. The important question about high school chemistry, or any chemistry, is, after all, not what topics shall be treated, but how they shall be treated. The value of the instruction based upon the study of hydrogen will depend entirely upon how the instruction is managed and the report in question included only a few rather vague hints in regard

* Delivered before the Chemistry Section of the Central Association of Science and Mathematics Teachers, April 10, 1903.

to the very thing which should obviously have formed its main burden. The only apology that can be offered for this negligence is that briefly to define the highly intangible features which distinguish good from bad instruction in a science is an exceedingly difficult task.

In turning the matter over in my mind, it has occurred to me that some definite conclusion might possibly be reached by handling the matter in the manner suggested by the title. Let us first analyze the pupil, his ability and his knowledge, as we receive him into the high school course in chemistry. Then let us analyze our ideal of the pupil as he should be after leaving our hands. Thus, by mere subtraction, we shall ascertain what the nature of the chemical instruction must be which will achieve the desired result with the materials available.

When we consider the question in this light, we perceive at once that there are really two pupils. There is, first, the pupil as we expect him to be, and, second, the pupil as we actually find him. It is highly important that the teacher should have a clearly focused conception of the pupil as he really is, since the benefit of instruction must lie chiefly in its perfect adaptation to the scholar's powers. So a brief discussion of the two pupils may be expected to furnish us with definite ideas as to what some of the genuine needs of the pupil will be, as distinct from the things which, from our mature point of view, and leaving the nature of the pupil out of consideration, we might like to give him. Let us, therefore, take these two pupils and subject them successively to analysis.

WHAT WE EXPECT THE PUPIL TO BRING.

In spite of the recommendation of the Committee of Ten, we are gradually adjusting ourselves to the arrangement of physics before chemistry in the secondary school, and in most cases, in the Middle West, at all events, these studies are placed in the upper years of the high school. Thus, we expect that the pupil will come into our hands with a knowledge of physics. We expect that he will have a definite knowledge of the chief principles of physics, that he will know how the most important constants are

determined, and that he will be familiar with the properties of matter as they are discussed by the physicist. We expect that we shall have little to do with physics, except to appeal to the knowledge which the pupil already possesses of the subject.

We anticipate that the pupil will be familiar with the use of the common rules of arithmetic and will be able to apply them to the solution of simple problems.

We suppose that he will have a certain amount of practical experience, to which we can appeal. We imagine, for example, that he will know better than to pour boiling water into a vessel of thick glass, that he will be able to recognize familiar odors and quickly to distinguish new ones. As a matter of fact, of course, we find that he can scarcely tell chlorine from turpentine.

We anticipate that he will be able to express himself in good English and to use words with discrimination.

There is one other thing which we seem unconsciously to expect, and this must account for the fact that we do not give instruction in it. We have accounted for the physics and the arithmetic in his previous training, but we have not yet defined the elements which the study of foreign languages, mathematics and history are to furnish. Naturally, as teachers of chemistry, we feel that these studies should be in some way tributary to the work which for us is the chief feature in the curriculum. What, then, may we expect from them? It seems to me that their study must have given the student a thorough knowledge of the scientific method. A little reflection will show that all the features of the scientific method are employed, for example, in acquiring a language. The pupil must have learned the value of a fact, and he must have learned to ascertain facts by the method of repeated observation and comparison in almost the same way that we expect him to continue the process in chemistry. He must notice the various ways in which a word occurs, and, ultimately, by comparing these occurrences with the statements in the dictionary and the grammar, he must form an independent conception of the exact significance of the word in each of the relations in which it is used.

I have said that he must have *learned* the value of facts. The pupil has to learn the value of facts, because the knowledge

of their value does not seem to be a natural attribute of the untrained human intellect. The history of mediæval medicine, for example, shows that the men of those times deliberately ignored facts and guided themselves almost entirely by preconceived notions in the most unscientific manner. Many prescriptions called for the use of moss grown on the skull of a murderer. Physicians recommended the cure of ague by hanging spiders or bags filled with chips from a gallows-tree around the neck of the patient. One physician, mentioned by Dr. Bolton in his "Follies of Science at the Court of Rudolph II.," gave a prescription for the cure of the plague, which was then coming into Europe from Turkey, of which the main ingredient was a decoction made from the flesh of a red-haired, spotless malefactor, who had been put to death either by beheading, impaling, or being broken on the wheel, and on whose corpse the sun and the moon had each shone but once. Half a pint of the extract was to be administered daily.

Plainly, if earnest men, many of whom were seriously striving to benefit mankind, could be so deluded, the fault must have lain in the absence of any general conception of the necessity of ascertaining the facts in regard to what conditions did and what conditions did not contribute to the occurrence and continuance of a given disease, and of what remedies might, and what might not be expected rationally to assist in its cure. Proper appreciation of facts must be an acquired and not a natural trait.

It is needless to point out in detail how the formation of generalizations from isolated facts, and the ultimate production of laws, is as much a feature of the study of language as of science. In all language studies, hypotheses and theories must be formed and must be tested by continual comparison with the facts, if any sort of organization of these studies is to take place. In short, the use of the scientific method in all its ramifications ought to be perfectly familiar to the pupil before he has actually come in contact with any science at all.

WHAT THE PUPIL ACTUALLY BRINGS.

A scrutiny of the pupil, as he really is, quickly shows us that we have been in many ways somewhat sanguine in our expecta-

tions. One strong point in his favor is that he usually comes with an interest in the science of chemistry. The popular conception of the chemist as a magician, who delights to spend his time in analyzing complicated and mysterious materials, raises the expectations of the pupil, although it at the same time, to some extent, misdirects him. On further examination, we find that his arithmetic is not what we expect it to be. The pupil seems usually to be unable to work the simplest problem in proportion. His practical experience seems somehow to have failed to furnish him with anything which he can use in chemistry. The knowledge of the scientific method, which we expect him to have, does not seem to prevent his acting and reasoning in the most unscientific manner possible.

On thinking the matter over, we perceive that we have expected too much, or, rather, we have expected the wrong thing. We are right in our analysis of the training he has had, but we are wrong in assuming that he will be able spontaneously to apply what he has acquired to a new subject without special guidance. The teacher in the secondary school wonders what the teacher in the grades can have been doing during the preceding eight years; the teacher in the college groans over the defects of high school instruction; and the professor in the university is depressed by the seeming inefficiency of all three put together. Yet, is it not apparent that the fault lies largely in each case with the instructor in the more advanced grade? He is expecting the impossible, if he imagines that any but the more brilliant pupils will be able, of their own accord, to apply conceptions and methods of a more or less abstract character to a new set of problems, without definite and specific guidance in this application from the new teacher.

The physics on examination turns out to be the greatest disappointment of all. A glance at a typical description of a secondary school course in physics will prove a surprise to any one who has not made a study of it with the definite object of noting precisely how much of the course may find direct application in the study of chemistry. Take, for example, the description of a unit course in physics, as given in the report of the Commission on Accredited Schools of the Association of Colleges and Secondary

Schools of the North Central States. The outline seems to describe simply the experimental work, and, since it is in the interpretation of chemical *experiments* that the knowledge of physics is chiefly to be used, this is precisely the part of the course in physics about which we most desire to have information. Under Mechanics and Hydrostatics, Part I., fifteen items are listed. The application, however, of the properties of levers and the coefficient of friction to chemistry, is not at all obvious. Of the fifteen items, only two, dealing with the specific gravity of solids and liquids, respectively, seem likely to be of use. Under Light there are ten items, dealing with the photometer, with mirrors, and with lenses, of which only two, concerning the indices of refraction of glass and water, promise to assist the student of chemistry. Some forcing is required to find any application even for these two experiments. We might conceive that they would direct the pupil's attention to properties which would enable him to distinguish chloroform from water, when the two liquids are shaken together, or to avoid the mistake of picking up a bottle containing concentrated sulphuric acid when the dilute acid is wanted. Under Mechanics, Part II., there are thirteen items, of which only three, Boyle's Law, the density of air, and elastic collision, seem likely to find application in chemistry. The list under heat is more hopeful, as it yields six out of eight items. On the other hand, Sound furnishes nothing, and Electricity and Magnetism, with the investigation of lines of force, and the putting together of telegraph keys, motors, and dynamos, supply only three items out of thirteen, namely, the study of single and two-fluid galvanic cells and the resistance of wires, which might form a basis for the explanation of some chemical phenomena. In all, out of sixty-two items, but sixteen might be expected to cut any figure in chemical experimentation, and of these sixteen a majority would find only the rarest, if any, application. Doubtless, the class-room work connected with the above is expected to touch upon many other parts of the subject which have a direct bearing upon the phenomena occurring in chemical work. But, after all, a more or less abstract discussion of these matters can not give that familiarity, which will make the explanation of a phenomenon perfectly

clear, when it turns up in laboratory work for the first time in connection with the new study.

It is thus evident that the physics which we expect the pupil to bring with him will be even less serviceable than the arithmetic or the knowledge of the scientific method, for not only will the capacity to apply it to a new subject be lacking, but the proportion of the whole of the material to be applied which the course in physics can furnish will be an exceedingly small one.

THE CONTENT OF THE UNIT COURSE IN CHEMISTRY.

These preliminary considerations enable us at once to specify the chief lines along which the effort of the teacher of chemistry will have to be directed, in order that a rational and symmetrical knowledge of chemistry, both experimental and theoretical, may be given. There will be three main objects, which must constantly be kept in view: to give a knowledge of the scientific method in its application to chemical work, to give a knowledge of physical phenomena and their interpretation, with the same application in view, and to give a knowledge of chemical facts and principles based upon the two former.

1. *The Scientific Method in Chemistry.* From what was said above, it is evident that the whole scientific method, as it exists loosely in the practice of the pupil, must be crystallized and developed until its application to chemistry becomes spontaneous. In language work, while the ascertainment of facts, the construction of generalizations, the employment of hypotheses, and the use of induction has been constant, these words themselves have probably never been used. It is evident that a more conscious employment of the scientific method is indispensable in work in a science. Perhaps this more conscious use of the method is now possible for the first time, since the greater maturity of the pupil will enable him to grasp the significance of the abstractions which the method involves, in a way which he could not have done before. It is at all events certain that the pupil's attention has to be directed afresh, for example, to the necessity of repeating observations, in order to secure accuracy. In one physical laboratory with which I am acquainted, the instructors

have an amusing tale in regard to a pupil who was measuring the diameter of a wire by means of a gage. The directions instructed the pupil to repeat the measurement in several places, and it was assumed apparently that the pupil would understand the object of this, note the slight differences between the separate measurements and take the average of the results. One pupil, however, came up to the instructor and said: "Mr. So-and-So, I have measured this wire in all the corners of the room; where shall I measure it next?" The pupil may have been exceptionally dull, but even the dullest pupil would not have misconceived the meaning of the directions so completely if the question had been one of comparing the usages of the same word in different sentences in Latin.

That attention should be called to the necessity of teaching the scientific method, not merely incidentally but systematically and in a certain degree formally, is demanded, not merely by the needs of the learner, but in view of the frequent carelessness, if not ignorance, of the teacher himself. The blunders in the use of terms involving a description of some feature of the scientific method, which are found in almost every text book of science, may safely be taken as an indication that even the best teachers are likely to use misleading phraseology, if not actually to inculcate entirely false conceptions. In a recent work by a well known chemist I find, for example, the following. He is discussing the theory of electrolytic dissociation, for which he has a great admiration, and adds, the "facts . . . can not only be interpreted by means of this theory, but are a necessary *consequence* of it." The italics are mine. The former phrase is intended to indicate that the facts are brought into interesting relations by means of the theory, and is entirely free from objection; but the statement that the facts are a consequence of the theory, or, in other words, that they occur because of the preëxistence of the theory, as the second phrase seems to imply, is simply grotesque. Yet this author repeatedly emphasizes the importance of theories by the employment of precisely this form of speech. Another book, whose authorship would at once prepossess us most strongly in its favor, describes the law of defi-

nite proportions as follows: "Any given chemical compound always contains precisely the same elements in exactly the same proportions. *No variation is possible.*" The italics are mine again. The definition is, of course, entirely correct, but the statement that no variation is possible must give the beginner the impression that this is a mandate from some high authority which has the power to enforce its commands. The fact is that *everything* is possible in the phenomena of nature, and the most prominent feature of all experimental work is the way in which unexpected things continually are found to happen. The intention was, of course, to say that no variation is known, or none has been observed. Farther on it is stated that when elements combine so as to form more than one compound, "the law of multiple proportions *comes into play.*" This phrase is less objectionable than the others, and yet it distinctly suggests that a new restriction of extraneous origin somehow controls the phenomena which nature is at liberty to exhibit. The fact is, of course, that, when variations from a single definite proportion for the combination of two elements are observed, we are able to construct a further statement known as the law of multiple proportions, which describes the limit of this variation. Laws in science are descriptive, not mandatory. From these examples, and they might be multiplied indefinitely, it is evident that if the principles of the scientific method are not specifically explained and illustrated—and usually, beyond defining the words theory and hypothesis, nothing is said about its principles in books on chemistry—the pupil must acquire but a hazy notion of the method when every now and again some mode of speech, which is inconsistent with the whole structure of scientific thought, is carelessly employed by an author or teacher.

2. *Physics in Chemical Experimentation.* It requires little reflection to enable one to realize that all chemical observation consists simply in the noting of physical occurrences and in interpreting them in accordance with physical principles. Furthermore, any illustration will at once reveal the fact that the parts of physics which are most needed in *chemistry* are precisely those which seem to be slighted in the secondary school course in physics,

if the outline of a unit course in physics which we discussed above represents in any way the main content of physical instruction. Take, for example, the heating of potassium chlorate. The substance melts. The pupil must realize that this is a common occurrence which does not necessarily imply any profound change, and may be reversed by cooling. Later the liquid appears to boil, and the pupil must know what the properties of a boiling substance are. If he has been informed in advance that the body is homogeneous, he must know that, if it is simply boiling, it will evaporate completely and leave nothing behind, and that the temperature required to achieve this will remain constant from the beginning to the end. In order, therefore, to become aware of the fact that here decomposition is taking place, he must note the ways in which the decomposition of potassium chlorate differs from ordinary boiling. For example, he should expect to find the solid body condensing on the sides of the tubes, and note the fact that no such condensation is observed, with the appropriate inferences. He should observe that, in the later stages at least, the agitation of the liquid does not cease when the flame is removed, although this would undoubtedly occur in a case of simple boiling. He must further observe the changes in the consistency of the material and the way in which it finally becomes thick and may even solidify. It is evident that we can not expect a beginner fully to interpret all that he notices. Some assistance will be required from the instructor. Not even the most practiced investigator could explain a phenomenon of this kind, which he was observing for the first time, without making a series of careful experiments of different kinds before he could definitely classify the nature of the phenomenon being observed. Perhaps all we can expect is that the pupil will notice that the phenomenon is certainly not one of mere ebullition. We could hardly expect him even to distinguish it from a case of the evaporation of a solution, obtained, say, by the melting of a substance in its own water of crystallization. Yet, even this theory would not explain to the thoughtful observer even the more obvious features of the phenomenon, for the liquid which was acting as solvent would have

to be amazingly volatile if the absence of any condensation on the walls of the tube was to be accounted for.

Whatever conclusions the beginner may be expected to reach in such a case, it is certain that the experiment must be baldly mechanical, and nothing more, if some knowledge of physics is not drawn upon during its performance. Now, there is hardly an experiment in chemistry which would not on examination reveal a similar necessity for the application of a knowledge of experimental physics, and indeed of a fairly complete mastery of physics, for its comprehension. How, for example, is a pupil to study the actions of iron and copper upon strong hydrochloric acid if he does not know the distinction between the boiling of a liquid, the evolution of a gas from a solution (both of which might happen in the case of copper), and the evolution of hydrogen (which will occur with the iron).

I had the curiosity to prepare a fairly complete list of the parts of physics which are required in elementary chemical work, and the catalogue was an astonishingly long one. Its most surprising characteristic, however, was the fact that most of the things included in it were but little likely to be familiar to the pupil who had studied elementary physics in a secondary school, or even in a college. Furthermore, the above illustrations show that general notions will not suffice. It is a highly specific and extremely ready knowledge of the details which is required. The student of chemistry, after we have put him through an elementary course, must have a much more highly developed knowledge of physics than, as a graduate from the course in physics, he had before we received him. Physical phenomena present themselves promiscuously in chemical work, and not systematically graded according to their order of difficulty as they do in the course in physics itself. The student of chemistry must learn to pick them out for himself, identify them at once, and handle then intelligently, without the assistance which a rational or even a conventional order would furnish.

One of the commonest difficulties which the pupil in chemistry has, is in distinguishing gases from solids and liquids. He must know that gases do not disperse light but transmit it. I

have hardly ever encountered a student, even in a university, who did not think that the fog rising from a locomotive was entirely gaseous. A perfect familiarity with the relations of matter to the dispersion of light is fundamental to the understanding of many experiments in chemistry which involve the production of fumes of one kind or another. The same field of knowledge is involved in understanding the difference between solution and suspension.

Again, under Heat, the high school list treats only of the response of gases towards the elevation of temperature, of specific heat and of the latent heats of fusion and vaporization. But the thing the student in chemistry requires is a familiar knowledge of phenomena connected with vapor pressure. Most pupils, for example, think that bodies produce the effect of having an odor by some sort of action at a distance, and do not realize that an intervening vapor is required. They almost never know that gases generated from aqueous solutions must be full of moisture. It never for a moment occurs to them that dehydrating agents act otherwise than by magic, and must be unable to remove moisture if their quantity is too small and the stream of gas too rapid.

Finally, not to enlarge the list, which could be extended almost indefinitely, the phenomena of crystallization and precipitation, the inferences in regard to solubility which we draw from the nature of the precipitate, the influence of the physical condition of a substance on its rate of solution, etc., teem with physical conceptions which have to be taught in the course in chemistry, if they are to be learned at all.

To avoid possible misconception, it must be stated specifically that the instruction in physics that *must necessarily accompany* the course in chemistry will not under any circumstances be of a formal sort, much less will the instruction be worthy of the name of physical chemistry. But whether the instruction is formal or not, it is quite certain that the thing itself must be taught in a common sense way, and that a large part of the time of the teacher of chemistry will be taken up with the effort to give this instruction. It is not a theoretical knowl-

edge of physics that is required, but an experimental and familiar knowledge that is needed. How is the pupil to understand that phosphorus pentoxide (*e. g.*) is not a gas, if, the first time such a phenomenon is encountered, the behavior of the substance is not compared carefully with that of a gas, and the means by which the fumes can be shown to be solid (or liquid, as the case may be) are not exhibited and explained? How is the pupil to carry out directions involving the saturation of a solution of a base with carbon dioxide or of salt with hydrogen sulphide if the test of saturation, by shaking the gas with the liquid in a vessel closed with the thumb, is not made clear to him, not merely by dogmatic injunctions, but by explaining how the test works? How can the pupil ever construct apparatus properly and manipulate effectively if he does not understand the physical properties of the apparatus and the physical means which he is using either for producing definite effects, or for the ascertainment of chemical facts?

Of course, almost the whole of this may be avoided if the pupil is instructed to make oxygen by heating potassium chlorate, and the object is simply to communicate a series of cook-book recipes for making certain substances, or demonstrating certain of their properties. The genuine exploration of chemical facts takes place by physical means exclusively, and the ascertainment of chemical results can take place in no other way than by an intelligent interpretation of physical phenomena. The chemical fact, as, for example, the exact chemical nature of a change, is the remotest of all the results of each set of experiments, and is reached by highly indirect inference and not by any sort of direct observation. If the physical side of the study of chemistry is neglected we are bound to fall between two stools, for the acquisition of a practical knowledge of chemistry itself must then become impossible.*

3. *The More Strictly Chemical Part of the Course.* While the importance of physical knowledge and physical reasoning has been strongly emphasized, they will be directed at all times with

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* This subject is discussed and illustrated more fully in Smith and Hall, *The Teaching of Chemistry and Physics* (Longmans, Green & Co.), pp. 30-37, 39, 69.

the settled purpose of leading up to chemical facts. It is not necessary to point out that, on the one hand, an excessive accumulation of chemical facts will only prove a burden, while on the other an over-meager assortment of chemical facts will harm the course by impoverishing it. However skilfully the instruction is conducted, it is certain that a large number of chemical facts will have to be brought to the notice of the pupil. In addition to these, and in fact as the real means of making them memorable and significant, we must have a thorough exposition of the generalizations of the science which sum up considerable ranges of single facts. The more important generalizations are those designated by the name of laws, like the laws of definite proportions and of combining weights. Then, for the further acquisition and better grasp of the facts and laws, and for the explanation of all chemical behavior, the various theories and hypotheses will be presented, as the necessity for them arises and data demanding interpretation accumulate. Finally, constant applications of chemical matters to every day occurrences and constant illustration of chemical principles by means of phenomena of general interest will be used, in order both to broaden the view of the pupil and to awaken and hold his interest.

The test of the efficiency of instruction in chemistry will not depend upon the number of facts which the pupil can recall, nor upon the accuracy with which he can recite definitions or reproduce theories. The pupil might conceivably have in his possession a phenomenal accumulation of fragments of chemical information, without knowing any chemistry at all. The test is that he shall be able to "think chemically," as the saying goes. This does not mean that he shall be able to think with the same precision and resource as a trained chemist, but that, in however small a way and within however narrow limits, he shall nevertheless be able to employ his knowledge in a rational manner. Thus, if we ask him how he would separate a mixture of hydrogen and carbon dioxide, he will be able, from what he knows of the properties of these substances, to suggest one or more ways of removing one of the constituents of the mixture. If he has been ill taught he will answer such a

question by saying that he does not remember any method, overlooking the fact that, not having been taught this precise thing, the appeal was not to his memory at all. If we ask such a pupil to perform some new experiment, we expect him to make some effort to take proper proportions of the substances, and to employ the substances, in whatever form they may be offered him, intelligently for the purpose. The beginner will take a test tube full of a solution of one substance and stop after adding a drop of the solution of another, without for a moment remembering that the laws of definite proportions and equivalent weights prescribe in a general way the principle upon which every new experiment must be conducted. We expect him to realize that, when phosphorus is oxidized in an aqueous solution, phosphorus pentoxide will not be formed, and that when sulphur is treated similarly the product will not be sulphur trioxide. Finally, to give but one other instance, he should be able to tell how he would make zinc chloride from zinc hydroxide or *vice versa,* or zinc hydroxide from zinc.

Summary of the Content of the Course in Chemistry. Summing up what has been said, we note that the pupil after a course in chemistry will have three characteristics. First, he will understand the scientific method and be able to apply it to chemistry; in other words, he will be able to think scientifically along chemical lines. Second, he will be able intelligently to apply physical methods to the making and interpretation of chemical experiments; in other words, he will be able to think in physical terms. Third, he will be able to reason in a practical way upon the basis of the chemical facts which he knows; in other words, he will be able to some extent to think chemically. All the rest that is involved in his instruction is simply the machinery for accomplishing these three ends.

THE MEANS OF INSTRUCTION.

Having thus focused definitely the result which we wish to produce, a few words may be devoted, in closing, to the means of instruction which are available. These are: The book, the

laboratory, and the teacher. We must confine ourselves to a very few remarks in regard to each.

The book has its value, and at the same time its marked limitations. Its value lies in the fact that it is a source of knowledge arranged systematically and presented more or less in the form of a summary. It is more complete than the laboratory work, for the descriptive part gives properties which are not studied, and many which could not be studied, by a beginner, as well as those which he did investigate. It treats of the principles of the subject, its laws and its theories, by clear statement, full explanation and sufficient illustration. It thus furnishes a definite record to which recourse may be had repeatedly until a perfectly clear conception of every principle has been secured. Its form enables the pupil also to acquire needed information speedily, provided he has practical knowledge sufficient to enable him to appreciate its statements. In other words, the book is primarily a work of reference.

The limitations of the book are especially worthy of note. The student who learns without an instructor or a laboratory never acquires a proper appreciation of the relative importance of the different parts of the subject. In spite of the attempts graphically to distinguish the important from the unimportant, by devices which we owe to the printer, the effort to classify the contents according to this principle never produces really successful results. The book also omits, and indeed inevitably must omit, the description of the physical details which are, after all, so to speak, the native language of the science. For the description of these matters realistically, language is totally inadequate. The book, therefore, wisely makes no attempt to supply laboriously what can be furnished by direct observation in a few moments. The book is thus necessarily abstract in its statements. It says that a certain substance is a base, but it can not continually repeat the description of all the phenomena which this term connotes. It states that a certain solid is very soluble, little soluble, or insoluble, in water, but only the pupil who has worked with materials having these properties has any definite conception of the physical behavior which these terms class-

ify. The book presents parts of each fact and furnishes much material more effectively than does the laboratory or the teacher, but its contents are half facts, nevertheless. The student of a book must always remain an amateur with a greater or less knowledge of detail, no sense of proportion, and no grasp of the principles. The teacher who is under the delusion that he can instruct by transferring the contents of the book into the heads of his pupils is preparing for himself the most dismal possible failure, at all events where the subject is an experimental science.

The laboratory, like the book, professes to do something which no other means can do, and at the same time it has limitations which are as marked as those of the book. What the laboratory can do has been discussed so fully that it is needless here even to enumerate the things which may be expected of it. For our present purpose we mention simply the physical detail, which it alone can furnish, and which is the basis of all practical chemical knowledge.

The limitations of the laboratory are set with the rigidness of a geographical boundary, and yet there is reason to fear that many teachers do not realize that it has any limitations. For example, the laboratory can furnish the basis for learning many facts, but it can never correlate facts or lead to the evolution of generalizations, principles, or laws. Clean manipulation is an important art which can be acquired nowhere outside of the laboratory, but the laboratory alone can generate nothing better than an artisan, destitute completely of any knowledge of the subject as a science.

As has been hinted, too much is sometimes expected of the laboratory. Professor Hall, in the book referred to above, gives an admirable illustration of this. In one laboratory manual of physics the pupil is directed to place a piece of wood upon the table and, after viewing it for some time, to write an inference. One can imagine all sorts of conclusions to follow a careful scrutiny of a piece of matter under such circumstances, but even a philosopher would be baffled in determining which particular inference was expected. It seems that in this particular case the pupil was supposed to write down that matter could not set

itself in motion of its own accord! He was expected, in other words, to create the conception of inertia. The next experiment required him to push the block about with his finger, and then, after due reflection, to write another conclusion. Here he was supposed to infer that matter was set in motion by force. It is to be feared that these examples are not entirely grotesque and imaginary.

The laboratory work is limited also by the time which can be devoted to it, and the consequent impossibility of covering all the facts which are required for rounding out the course. It must furnish the basis for much study, by giving samples of the various kinds of phenomena that may be observed, and leave to the teacher and the book the task of applying them by analogy to other cases.

Finally, the phenomena observed in the laboratory are destitute of any power to call attention to their own occurrence, and they are still more conspicuous for the fact that the most prominent ones are sometimes the least significant. The antics of a piece of sodium thrown upon water are far more conspicuous than the other details which really tell more about the chemistry of the change. The knowledge of what to observe is not natural but acquired. The gelatinous character of a precipitate is not likely to strike a pupil unless attention is called to the fact that other precipitates are granular and still others crystalline. In other words, there must be multitudes of details which come under the notice of the pupil, but are not observed by him in the strict sense of the term, and are likely soon to be forgotten.

The laboratory, like the book, furnishes simply fragments of facts. These fragments are exclusively of a physical nature, and constitute the raw material from which, after due discussion, significant truths may be extracted. Things worthy of notice must be recalled, the facts must be selected and completed, and the generalizations and principles must be developed from them by some other agency. The laboratory without the teacher is as incomplete as the book without the laboratory.

Each pupil is a constant quantity which must be accepted as he is. It is for the teacher to find out what he is. The book

after it has been chosen must also be taken as it is, and it is for the teacher to realize what a book, and what this book in particular, can do. The laboratory work must also be taken as it is, and the teacher must be thoroughly aware of its limitations. The teacher is the one variable element. The success of the whole course must depend upon his versatility and powers of adaptation. He must round out the fragments of facts; he must correlate the facts with one another; he alone knows when to mention a new fact, and when to introduce a theory; he adapts everything to the moment, the individual and the occasion. Drawing upon his knowledge of industrial chemistry, historical chemistry, physiology, geology or mineralogy, he must take the initiative in illustration and application. Using his knowledge of educational principles, he must see things from the pupils' point of view, and know how to hold their interest and attention. Finally, from his reading and experience in genuinely scientific chemical work, he must furnish that which none of the other agencies can give in the smallest degree, namely, some touch of the true spirit of the science.

If the teacher is wooden the whole instruction is bound to fail. If he allows the pupil to absorb a stream of fragmentary facts without proper discussion and explanation, the scholar may become filled with a breccia of petrified fragments of science, but he will never learn any chemistry. The teacher must have a complete command of the scientific method, a practical and resourceful knowledge of the physical phenomena in terms of which chemical facts come to our notice, and he must have a command of the science of chemistry as a science and not merely a disjointed knowledge of some of its conclusions. No one can gain a fluent command of French from an instructor who does not speak the language, and no one can learn chemistry from a teacher who is not a master of the science and of how to teach it.

Dean Farrar is quoted once to have said: "Classical education neglects all the powers of some minds, and some of the powers of all minds."

THE MICROSCOPE AND LIFE.

BY EDWARD F. BIGELOW.

Stamford, Conn.

"What is life?"

The simplest, most universal and stupendous phenomena are those of the distinctions between living and lifeless things. The more careful the observations, the greater the wonder. Bring to bear upon the subject all the accumulated knowledge and all the skill of the greatest intellects, and the answer to the question, "What is life?" still tarries. It is the ever fleeing will o' the wisp that leads the followers through fields and byways more and more enchanting. Greatest values lie not in the goal, which may never be reached, but in the race itself.

Even to the most unobservant, at least, one of the threefold divisions of this great question must appeal with deep and peculiar significance—what it is, what its origin and whither its tendency.

In the investigation of this greatest of mysteries, the most efficient aid is the microscope. By it we enter the hidden, fascinating and mysterious realm where the processes of life go on beyond the power of the unaided eye to detect.

This instrument, whose performance seems almost to be in the field of magic, has enabled us to reach the wonderfully little on earth, as the telescope has helped us to explore the stupendously great of the heavens above.

Beneficial, indeed, is the microscope in the arts, in commerce—in the examination of fabrics, and the detection of adulteration. It is of great utility in the study of rock structure and the identification and study of minerals. Profitable and pleasant is it likewise in observing the formation of crystals, and it has rendered much service in the advancement of chemistry. But vastly more than all these is its utility in investigating the processes of life.

In the life of every human being, fundamental questions are the first to appeal to growing intelligence. "What is this?" "What is it for?" All young children are true observers—natural scientists. As age advances, the greater part of mankind chooses or is forced, in the struggle for existence, to ignore these great questions

and to give chief attention to the affairs of so-called everyday life—business, society, politics, art or diversion. The great problems are set aside as if they never existed or have been all fully solved.

But to the comparatively few, the question "What is life?" never loses its interest, nor the wonderful microscope its efficiency. It is to these that biological microscopy holds fascination as one of the grandest sciences—one of the highest occupations of the human mind.

Biology demands close, careful, accurate observation. Objects intended only for examination by the unaided vision demand as much care as do those prepared for the use of the highest powers of the microscope. But observation is not all. Those who have unlocked some of the mysteries of nature have, in many instances, been aided by scientific imagination, by the creation of a hypothesis, to be worked up to and demonstrated if well founded, or discarded if incorrect. The abandoning of fallacious hypothesis has been difficult for some biologists, who have cherished their theories as a parent would cherish a crippled child, clinging to them fondly, although no fact can be so twisted or distorted as to fit into the grooves prepared by an overzealous fancy.

Fundamental and primitive among the working hypotheses of biological microscopy is the nature of the energy that we call life. Till demonstrated, if such a remote and much desired ultimatum were possible, all investigations must be arraigned for or against the correlation or equivalence of life with the forms of energy discussed by the physicist.

What are its relations to light, heat, electricity and chemical forces? Is the phenomenon of life due to any or to all of these, or is it the effect of some unknown and undiscoverable agency? The present state of science, while not issuing a positive edict, does at least favor with some probability of correctness the hypothesis of a force different from any at present known in the domain of chemistry or of physics.

The living matter in the cell was originally called protoplasm, but in 1872 Professor Beale introduced the word bioplasm and applied it exclusively to living protoplasm. By some scientists the terms protoplasm and bioplasm are used interchangeably, but

the original intent of the term bioplasm, if closely adhered to, makes a convenient distinction.

According to this view, protoplasm is always protoplasm, "the physical basis of life," dead or alive—even if cooked. With death, bioplasm ceases to be formative matter, and becomes so much ordinary dead protoplasm or formed matter.

Bioplasm is, therefore, living, growing, active protoplasm; living, growing protoplasm is bioplasm. Dead bioplasm is only dead protoplasm, and dead protoplasm is dead bioplasm. At present, however, this term bioplasm is but little used by scientists. Protoplasm applies to both the living and dead basis of life.

Animal or vegetable matter that has accomplished its growth, when it no more increases by division or by addition of new matter, when it simply lives unchanged is formed of protoplasm, but is not correctly bioplasm, for bioplasm must manifest activity in the form of increase and reproduction.

Protoplasm may be alive and quiescent; there can be no such thing as entirely quiescent bioplasm. When bioplasm becomes quiescent, it has ceased from formative work and become formed material. It lives, but as a quiet protoplasmic structure, complete morphologically and about ready to die and disappear, to give place to some active protoplasm which then becomes bioplasm.

In this animal and vegetable bioplasm, which may be obtained in many ways, are to be observed the phenomena of life. Magnifying power, only sufficiently high to do this work, to show structure and action is the best. It is probable that no means will ever be devised whereby a knowledge of structure will result in a knowledge of the cause of action. How this transparent bioplasm does its work is information that could probably not be obtained if the ability of microscope objectives could be increased even beyond the theoretical limit of resolving power of 146,543 lines to the inch in white light, or of 158,845 in monochromatic blue light.

To make a chemical analysis of living matter is at present impossible. Biologic investigations must then be chiefly by microscopical methods. The question naturally arises: Why pursue a science that offers not even a probability of an ultimate reward? The What is the Infinite, and is not to be comprehended by the

finite. Demonstration can be made of what life is not, and observations of what it does may be made with much profit.

The nucleus is the point at which the life of the cell centers; there is no known living cell without a nucleus. This has been proved by the observations of scientists, who cut an infusorian into several parts, and each lived, grew, and reproduced itself, provided even a small portion of the nucleus was retained in the part, but died if no portion of that complex structure remained. Thus the life of the cell is now known to be centered in the nucleus.

We know imperfectly and incompletely the structure of the living, and the chemical composition of the dead nucleus, but the life itself eludes us.

Reproduction and growth always begin in the nucleus; reproductive formation always begins with the union of two living cells. This is seen, almost at will, in certain infusoria. Two of these minute aquatic animals meet, apparently by chance; at once the two bodies become united, the protoplasm (bioplasm) of the one mingles with that of the other, and the nuclear changes take place and new individuals are formed.

In the nucleus is the potential throne of life, where life abides, makes its laws, and whence it issues its commands. Whatever the life of this cell may be, it is primarily in the nucleus.

Biological microscopy, therefore, chiefly concerns itself with the study of the cell and its nucleus, asking these questions:

1. What is life?
2. What are its relations?
3. What does it do?

"What is life?" then becomes the great question to be considered in threefold relations—essence, associations, and activity.

A comprehension of life itself is not within the power of life. It will doubtless remain "the great mystery," before which there stands a Great Unknowable that says, "so far shalt thou go and no farther." Of this great Infinity, science knows and can know nothing except to name it p-o-w-e-r, or l-a-w. It has been made known only through revealed religion and is called God; and even then only sufficient made known for needs rather than to gratify curiosity, with promise of knowledge in its fullness, when the val-

ley of this life shall be viewed from the summits of the mountains of the eternal and real life.

In its associations, the manifestations of life closely ally it with the powers of chemistry and physics, but at the same time distinctly separate it from both. The physical basis of life, protoplasm or bioplasm, can be analyzed. But the reverse process is impossible. The constituent chemical elements can never be recombined nor the physical phenomena so stimulated as to produce life. Destructions may be from various causes, but production only from natural sources and from previous life. Since matter and life were created, the first, so far as we know, can neither be produced nor destroyed, and the latter can not be created.

"Omne vivum ex vivo" is the unchangeable biologic edict. Scientific evidence is more and more convincing and conclusive regarding the direct operation of vital power. The difference between life and death and the difference between all kinds of growth in the living and all kinds of aggregation in the non-living are, always were, and forever will be absolutely different and irreconcilable.

Life is not the outcome of mechanical and chemical forces, though it may utilize both for its welfare.

Some physicists and chemists, using improved instruments and methods of research, investigating with marvelous delicacy and approaching nearer absolute knowledge, have naturally looked forward to the discovery of something basic in the living thing that can be taken apart and put together; chemists have been deluded by this theory of synthetic life.

The microscope in biology destroys this hypothesis by demonstrating that the primal cell is not merely a compound but a structure, not a syntheses of masses, but a machine.

A machine implies more than a combination. There is back of it a formative, designing mind. Mixture is not enough.

No substance has yet been nor can be discovered in the laboratory that will live, move and grow like every particle of matter that has lived, moved and died. The gulf between the living and nonliving grows wider and wider with the advance of biological microscopy. There is no reason for thinking it ever can be bridged or filled up. The microscope has not yet disclosed any intermediate

stage, no half life or half death in case of a definite cell of bioplasm. One may be more active than another, or at other times, but it is in all cases either life or death.

Biological microscopy demonstrates that all living matter has a position of its own, difference in origin, multiplication, growth and action, and influence of environments that are distinct, in fact, superior to physical and chemical laws, often overcoming them when in opposition. The laws of matter are not the laws of life. Life is distinct from chemical and physical laws, though associated with them.

The third division of biological microscopy, a consideration of the activities of life, is the most prolific in definite and satisfactory results. A drop of water from an aquarium or a pool reveals on microscopical examination a world of things, not unlike the scenes on a street.

Many things, some living, some not. A simple particle of life, the amœba is well worth careful consideration. Though but a speck of matter, it is still living and shows life in many of its manifestations and activities. A portion of the protoplasmic body extends and the rest is drawn to it. It approaches a bit of material and leaves it or surrounds and assimilates it as food. From the food material engulfed, the nutrient portions are transformed into its own living substance. In the very beginning of its life there are the phenomena of locomotion, choice, nutrition, and reproduction. One little mass of living matter has performed all the functions of life.

Perhaps the larger and more complex forms, not even excepting man, are but aggregations of cells in which duties are even simpler than in amœba. Instead of all the duties of life being performed by one cell, there are cells specially assigned for various functions; some digest, some feel, some reproduce the species, and others are differentiated for various specified duties. The study of these specialized cells demands the use of the microscope and yields satisfactory results.

Among the activities of life as revealed by the instrument, none are more interesting or wonderful than the self-sacrifice of the leucocytes or white corpuscles of the blood. They take up

minute impurities, carry their load out and free the body, but they themselves perish. No patriot, in dying for his country, ever exhibited more self-sacrifice than these little corpuscles, the guards of the body.

The study of activities involves the study of structure. Modern research, with improved lenses, shows that a cell is not, as its name implies, a vessel empty or filled with fluid, but is itself a highly organized, differentiated structure. Its contents are not a homogeneous mass, but in intricacy of structure and diversity of duty nearly, if not quite, rival that of the whole structure. The nucleus, the astrospheres, the centrosome and the network of chromatin have each an individual and distinct function to perform. As with the various cells of the whole structure, so in each part of the cell there is a willing assumption of individual responsibility.

These are but the gates, fascinating though they be, to the great fields of biological microscopy. Upward through the series, from low to high, in parallel lines of zoölogy and botany, the investigation may continue.

To diversities without confusion, to beauties of great attractions, to wonders that instruct as well as amaze, to mysteries that baffle but never discourage, are the invitations of biological microscopy.

Structure, functions and activities have their great reward, but the microscopist who has witnessed growth has been near to a natural phenomena, even more awe inspiring than death. It is not in death but in life that the ground is holy. Witness the growth of a slender filament from a pollen grain, or the extension of a thread of fungus, and the microscopist achieves a result worth many hours of patient toil and study. It brings the observer closer to the Great Infinite that we know is near us at all times, but from which our present limitations exclude us from full communion. Only a glimpse into the Great Unknowable. Not forever shall the veil intervene. "For now we see through a glass darkly; but then face to face."

The microscopist, in researches in biology, can go forward with enthusiasm and hope, that although research will never answer

the great question, yet is he confident that as each generation adds a little certain knowledge to the world, there may come in time an accumulation of facts regarding living substances, so complete that while the great mystery voiced in that greatest of scientific questions, "What is life?" may not be answered except in its activities and phenomena, there may cease to be the supreme question in its essence.

Through cell structure, simple individualism, greater differentiation, even to highest complexities, biological miscroscopy leads its devotee. And at each advancing step towards the Great Mystery our appreciation of Luther's statement, "To have studied well is to have prayed well," should increase.

AN EXPERIMENT IN RESONANCE.

BY E. C. WOODRUFF,

Instructor in Physics, Lake View High School, Chicago.

Without doubt the most important things in elementary acoustics are these: (1) Simple Harmonic Motion. (2) The relation between frequency, wave length, and velocity, and all that grows out of it. Consequently the more experimenting the pupil can do along these particular lines, and especially the more elaborately any experiment he does perform can be interpreted by him, the more definite and important will be what he may get out of the subject. Sound is a part of physics frequently more or less neglected, especially in an experimental way, except in so far as it is taught as a collection of curious and interesting phenomena. As a matter of fact, given Melde's experiment, Kundt's experiment, experiments on the vibrations of coiled springs, the tuning fork chronograph, and experiments in resonance, not to mention graphic constructions for simple and complex wave forms and for

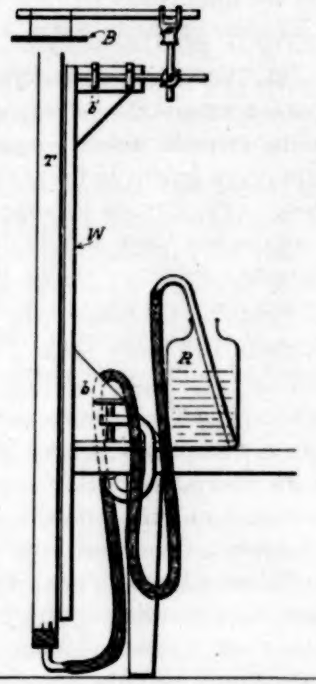
Lissajou-figures, the subject becomes the richest laboratory subject in physics from the mechanical standpoint, and also as a preparation for the study of some of the same kinds of motions in light and heat, where the phenomena are not as readily handled in the laboratory, at least by a beginner.

For some of these experiments the question of procuring suitable forks is a serious one, especially if one wishes to make the experiments something more than qualitative or limited in scope by putting variety into them. It then becomes necessary to have several forks or other vibrating bodies to contrast. This applies especially to the experiments on resonance. But here at least we have a very easy way out of the difficulty. Rectangular bars, than which few things can be procured more easily or in greater perfection, will very efficiently take the place of numerous forks and will give all the variety in conditions desired.

An extract from a pupil's note book and a drawing is here given to illustrate this point. More bars might have been advantageously used, a sufficient number perhaps to have covered the notes of the principal chords of the scale.

APPARATUS—The apparatus was set up as in the figure. *W* is a wooden upright fastened to the table by means of the bracket *b*, and carrying at its upper end the bracket b^2, to which are fastened the clamps that support the vibrating body *B*. To the front of *W* is fastened the glass tube *T*, which tube is connected by means of rubber tubing to the bottle *R* as shown. Raising or lowering *R* changes the level of the water in *T* as may be desired. The bars were of steel of the dimensions given in the table, and were hung from the support by means of strings tied one-fifth of the length of the bar from each end.

OPERATIONS.—The bar under test was struck with a small copper mallet. *R* was raised or lowered until a point was found where the sound was the most strongly reinforced. The level of the water was then read by the aid of a meter stick fastened to the tube. Thus were obtained columns 1, 2 and 3.



	Resonances.			Average ½ Wave Length.	Temperature.	Velocity.	Frequency.	Dimensions.
	Upper.	Lower.	Number Between.					
Fork 128 v. d.	6.5	140.8	0	134.3	2)	344	128	
Bar C_4	11.6	97.8	9	8.62	25.8	348	2018	15.7x2.5x9.5
Bar A b_3	14	96.8	7	10.35	"	"	1681	24.2x0.6x2.5
Bar A b_2	8.7	93.4	3	21.17	"	"	821	32.3x0.6x2.5

The readings and the dimensions are in centimeters, the velocity in meters. The diameter of the tube was 3.7 cm.

CALCULATIONS.—(1) For the fork the maker's stamp of the frequency was taken as correct and the velocity of sound in the tube was calculated from the formula, velocity equals frequency times wave length, where the wave length is twice the distance between the points of resonance. (2) For the bars the theoretical velocity at the observed temperature was taken and the frequencies were calculated from the formula, frequency equals the velocity divided by the wave length, where the wave length equals twice the distance between any two points of reinforcement divided by a number one greater than the number of points of resonance between.

INTERPRETATIONS.—(1) The velocity as calculated from the data given by the fork is 344 meters instead of 344.4 as found by standard authorities, an error of less than 0.2 per cent. Then, if the fundamental formula connecting wave length, frequency, and velocity is true the distance between successive points of reinforcement must be one-half a wave length. (2) From the frequencies found for the bars and the dimensions of the bars, we get the following:

The squares of the lengths of bars Ab_2 and Ab_3 are 1043 and 585.

The ratio of the squares is very nearly 2 to 1.

The ratio of the frequencies is very nearly 1 to 2.

We conclude that in bars supported as these were and caused to vibrate transversely the frequencies are in the inverse ratio to the squares of the lengths, or the frequency varies inversely as the square of the length.

Bars Ab_2 and Ab_3 are an octave apart. The ratio of their frequencies as found is very nearly 2 to 1.

Bars Ab_3 and C_4 are a third apart. The ratio of their frequencies as found is very nearly 4 to 5.

These results agree with the ratios as given in the physical theory of music.

THE HANDLING OF NOXIOUS GASES IN THE HIGH SCHOOL LABORATORY.

BY HARRY CLIFFORD DOANE.

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One excellent service that the newer text-books have rendered the teaching of high school chemistry is in the simplification of the apparatus and methods of their illustrative experiments, both for class room use and for the laboratory. None of the text-books, however, have given special attention, so far as I know, to the handling of noxious gases in laboratories that are unprovided with suitable ventilating hoods. The authors all take it for granted that all schools have these very useful contrivances; but unfortunately a very large share of our schools do not have them, and where they do have them, they are usually so few and so small that they cannot be satisfactorily used in most laboratory exercises.

This matter is one of great importance. It is assuredly not right for the teacher and pupils to work in poisonous and irritating fumes, and this must be done, if the usual text-book methods are followed in a laboratory without ventilating hoods.

In the Grand Rapids Central High School we enroll about one hundred pupils in chemistry. When the building was erected ventilating hoods were constructed, but for some reason they worked so poorly that they were removed previous to my coming to Grand Rapids. So we have been working on the problem as it has confronted us in this school. This is written with a hope that some other teachers may be helped by the methods that have proved successful with us. The methods themselves are not original, as will be seen. As an indication of our success in avoiding the bad results of handling bad gases in the open laboratory, I would say that our laboratory has been unpleasant from bad fumes but once or twice during this school year. I believe that we have not sacrificed anything of importance to gain this end. Fortunately our laboratory has fair general ventilation.

The apparatus that we use in the preparation of chlorine is a modification of one suggested by J. A. Giffin in his little book

entitled, "A Handbook for Teachers of Chemistry in Secondary Schools," a book full of good suggestions. The accompanying sketch (Fig. 1) will give at once an idea of how it works. The flask (*a*) is one of 125 c. c. capacity. From this a delivery tube

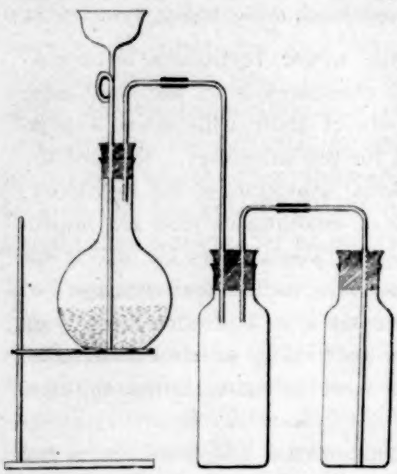

Fig. 1.

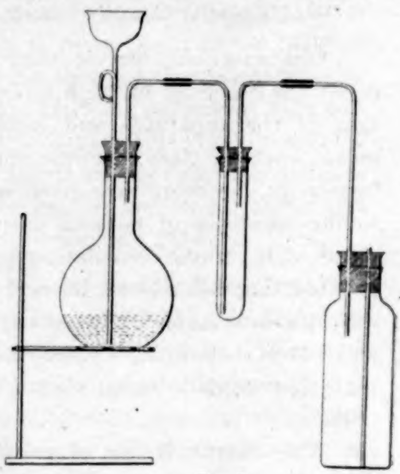

Fig. 2.

extends nearly to the bottom of a rubber stoppered 20 cm. test tube (*b*), from which again a tube leads to a rubber stoppered half liter (or perhaps better liter) bottle (*c*), having an exit tube extending from its bottom. The bottle (*c*) is filled with water and stands in a pan to catch the overflow. As the gas passes over into the test tube, the air and superfluous gas displace the water in the bottle. Calico, indigo solution, sodium, etc., can be placed in the test tube. When one has been used, another can be quickly put in its place. When through experimenting with the chlorine we set the whole apparatus outside the window until all action ceases and all the accumulated chlorine has escaped. Great use can be made of the window ledges in this way. In one school where they were too narrow, I made a shelf outside of the window for this purpose. At the beginning of the experiment each pupil may warm an evaporating dish and pour into it two or three cubic centimeters of ammonia, and place it near the apparatus. This will help to neutralize any chlorine that may escape. Hydrogen sulphide and sulphur dioxide may be handled in the same way.

Gases that are collected over water, such as nitrous oxide and nitric oxide, can be handled in the usual way without trouble, provided small amounts of materials are used and pupils are especially cautioned to be careful. With nitric oxide it is best to remove the apparatus and all used receivers to the outside window ledge as soon as possible after using. Keep covers on the receivers until they are placed outside of the windows.

Hydrochloric acid and ammonia can be easily handled by arranging the apparatus as in the sketch (Fig. 2). The bottles are filled about one-fourth full of water and the tube extends just into the water in the second bottle.

It does not seem best to have pupils attempt Marsh's test for arsenic in the open laboratory, and it may be wise to omit the preparation of carbon monoxide, as this gas, being odorless, does not give warning when escaping.

Nitric acid can be nicely prepared by using a 20 cm. test tube with cork stopper and delivery tube, collecting the acid in a small test tube standing in a pan of water. Use only a small amount, one or two grams, of sodium nitrate. For the class room bromine may be prepared by the use of the same apparatus as used for nitric acid, except that the test tube in which the bromine is collected should be partly filled with water.

We have found it hardest to find a satisfactory method of handling hydrogen sulphide. As suggested above it can be managed the same as chlorine in the study of the gas itself, but in qualitative analysis it is a harder proposition. We are using the solution, believing this to be better, even with its disadvantages, than to suffer the annoyance of using the gas in the open laboratory. The solution does very well where only a small amount of time is given to qualitative analysis, and I believe we ought not to give it much time in the high school.

In some of these experiments two pupils can advantageously be allowed to work together. This makes the danger from escaping gases less. When teaching in a small school I used frequently to take my classes out of doors for some of the experiments.

To be successful in this, as in all laboratory work, the teacher must keep everything well in hand himself.

Metrology.*

GOVERNMENT'S ABANDONING OLD WEIGHTS AND MEASURES.

In the American Society of Civil Engineers a progress report was presented at its annual meeting, January 21, 1903, by the Special Committee on Uniform Tests of Cement. Its paragraph 53, under the head of Mixing, is as follows:

The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

The report uses metric measure very freely, but it also makes some use of the older customary weights and measures. There is a great deal of the confusion of old practice yet to be done away with in order that we may fully enjoy the uniformly simple relations of the metric system. The same is true in electrical engineering, as to which Appendix 4 was added to a report of the Committee on the Metric System in the American Society of Mechanical Engineers, recently submitted. It was added by avowedly anti-metric members of that committee, and is as follows (p. 685):

USE OF THE METRIC SYSTEM BY ELECTRICAL ENGINEERS.

Electrical engineers are said to be largely using the metric system. They are in fact using a mongrel system, comprising the C. G. S., or absolute system, the metric system with the centimetre instead of the millimetre as the unit, English feet, inches and square inches, and several different wire gages. In a pamphlet on dynamo design recently published are found the following:

Lengths, thickness, etc., 34.9, 20.85, 0.05, 0.706 and 1.16 centimetres.

Speeds, 1.300 and 1,735 centimetres per second, 3,500 feet per minute, 50 feet per second.

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* Communications for the Department of Metrology should be sent to Rufus P. Williams, North Cambridge, Mass.

Areas, 3,242 square centimetres, 2.2 watts per square inch (= 0.341 watts per square centimetre), 600 circular mils per ampere.

Volume, 3,880 cubic centimetres.

Resistance of 1 centimetre of No. 6 B. W. G.

Lines of force, 7,800 per square centimetre.

This is a sample of the confusion that has already resulted from the introduction of the metric system into English literature on electrical engineering. Before a dynamo can be built in any ordinary American machine shop the metric sizes have to be translated, thus: 1,735 centimetres = 56.9 feet; 34.9 centimetres = 13.75 inches; 0.05 centimetres = 0.02 inches; 3,242 square centimetres = 502.5 square inches; 3,880 cubic centimetres = 236.7 cubic inches.

As to the present state of opinion with regard to the introduction of the metric system the following representation was made by an earnest opponent of metric reform, Mr. F. A. Halsey, in the first paragraph of his article "The Metric System," presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, referring to a bill then pending in Congress reported from the House Committee on Coinage, Weights and Measures, and to the testimony before that committee:

Scientific and practical men of the front rank, as well as engineering, scientific and trade societies everywhere, are calling for this measure. The Western Society of Engineers, by a mail ballot, voted for it by over 5 to 1. The Franklin Institute, with Samuel Vauclain, James Christie, and Wilfred Lewis on its committee, has also indorsed it. With the report of the Franklin Institute were transmitted to the House Commitee twenty-one letters from "various large manufacturing firms, particularly manufacturers of machinery" (page 104), which had been received in answer to a circular letter of inquiry, of which twenty favored the metric system.

A canvass has been made in the National Association of Manufacturers, which was made public in the report of its Committee on Weights and Measures submitted at its annual convention at New Orleans (April, 1903). Out of 223 manufacturers who answered Question No. 8, as to the extent of their practical

experience with the metric system, eighty stated that they had made some use of it, as follows, according to the classification of the committee (given in *American Machinist*, vol. 26, p. 595, for April 23, 1903):

Very little	15
To a limited extent and in a few instances	8
In some departments	2
In one department	2
In laboratory	5
In foreign business (export or import)	27
In special cases or when required	13
In correspondence	3
Some	3
Largely	1
Whenever possible	1

The use of the metric system in foreign business by twenty-seven of the manufacturers is somewhat similar to its use by the United States Post Office department for international business.

Those adoptions of the metric system by large corporations have been made as their managing men thought best. The United States government, which is a still larger user of weights and measures than any private corporation, is introducing the metric system in its business; and it behooves the voters of the United States, who control the management of its affairs, to determine as to its abandonment of ancient weights and measures.

The government's introduction of the metric system has been made in an irregular way at different times by officers acting independently of one another. In medical service, for instance, the metric system was introduced in the Army in 1893 under the direction of Surgeon General Sternberg, in the Navy about 1885, and in the Marine Hospital service (under the Treasury department) in 1878. If the completion of the government's change should be with no better guidance than thus far shown, the remaining steps might be taken in similar haphazard fashion as the departmental officers might be aroused, or as political changes might occur; and the transition process might therefore be protracted to an uncertain length. Evidently it will be advantageous for us to have the change in government business go forward in a sys-

tematic, concerted way and end within a moderate term of years. To propose a term of years that shall be admitted to be sufficient, we may search among the various estimates that have been thoughtfully made for the longest ones, since the greater includes the less.

With reference to internal revenue taxation, eight years was the time estimated by Mr. Charles A. Bates, an officer in that division, to be required to complete the abandonmnt of old weights and measures, according to the reported testimony before the Committee on Coinage, Weights and Measures in 1902 (pp. 63-4). This was because of the law permitting the storage of liquors in bonded warehouses for eight years. Referring also to the assessment of duties upon spirits another conservative estimate was made in 1878 by Julius E. Hilgard, then Superintendent of United States Standard Weight and Measures, subsequently Superintendent of the United States Coast and Geodetic Survey; he had long been using the metric system in that service and had taken great interest in the movement for its general introduction. Writing in reply to a resolution of inquiry of the House of Representatives he said, among other things (Report No. 53, H. of R., 45th Congress, 3d Session, also Report No. 14, H. of R., 46th Congress, 1st Session):

> The general answer to the question of how long a preliminary notice should be given before the obligatory use can be introduced without detriment to the public service, necessarily depends largely upon the estimate of the time that must elapse before the people become practically acquainted with the new system. So far as the matter of the collection of taxes upon spirits is concerned, it is the opinion of this office that it should not be enforced before 1890, in order to give time for the instruction now given in public schools to reach a large number of officers and persons engaged in the business.

Proposing 1890 in a report dated March 21, 1878, allowed more than eleven years' time. If a similar spirit of conservatism were applied to the question now, it may be assumed that somewhat less time would be fixed, in view of the progress that has been made during the quarter century which has subsequently elapsed, not only by the continuance all the time of the instruc-

tion in schools and of the use of the metric system in coinage, but particularly by the extension of its use for electricity, already referred to, and by the enormous increase in the foreign commerce of the United States.

(To be continued in November.)

NOTES.

Society for the Promotion of the Metric System of Weights and Measures.—A few members of the American Metrological Society got together in Washington, April 25, for the annual meeting and election of officers. Radical changes were made. The name of the society was changed to that given above, and yearly dues were reduced from $5 to $1, Several letters were received from absent members and some discussion was entered into. The officers of the new society are: President, Dr. A. E. Kennelly, Cambridge, Mass.; secretary, W. L. Crounse, Washington, D. C.; treasurer, J. H. Gore, Washington, D. C. Dr. W. H. Seaman was made chairman of a committee on textiles, and Jessie Pawling on secondary schools

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National Association of Manufacturers.—A committee appointed by this association one year ago to ascertain the opinion of manufacturers on the metric question reported at the annual meeting April 14, 1903, at New Orleans. As was expected, a majority were opposed to any change. The total number of replies was 264. Of the eight questions asked, some were ignored, but a fair average of the categorical answers showed about three opposed to a change to one in favor of it. One question, taken as a type, as others are quite lengthy, is: "Would the adoption of the metric system tend to increase foreign business in the line you represent?" The answers were: Yes, 60; no, 175; noncommittal, 12. The *American Machinist* of April 23 gives a summary of the report.

Metric Catalogue.—The American Locomotive Company has issued a catalogue, in English and French, which gives weights and dimensions in English terms and also in their metric equivalents, so that the reader in any country may obtain a correct idea of sizes and capacities. As this company has eight large locomotive plants and is second only in magnitude to the Baldwin company, the use of metric dimensions is proof that American manufacturers can make machinery to metric as well as to English measurements.

R. P. W.

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

PHYSICS.

Wave Tank.—Anyone can have a very large wave tank by laying four sticks, an inch or more thick, on a table so as form a rectangle, and then throwing over them a piece of flexible oilcloth. The tank can be emptied by separating the sticks at one corner and tipping the table. Such tanks are useful for experiments such as those with floating magnets, which are apt to give trouble by running to the sides of the vessel. The tanks are specially useful in the study of light, where they help to a conception of the real nature of the waves of light such as the study of "rays" in diagrams could never give. Diffraction, reflections of all kinds, and conjugate foci are strikingly represented. It is even possible to demonstrate the cause of refraction. The method (the name of whose author I have unfortunately forgotten) is as follows: A plate of glass or a board is supported in the tank in such a way as to make the water over it much shallower than elsewhere. Waves are then seen to move more slowly over the shallow portions, and this change of velocity causes a change of direction when the wave strikes obliquely on the shallow part. By making the shallow spot in the form of a very large and thick lens the formation of a focus can be shown, though imperfectly. Circular waves are best started, not from a point, but by using the bottom of a large dish or other circular object, to get more energy. Plane waves can be started with a board. It is well to use white oilcloth and color the water. The crest of the wave, on account of the greater thinness of the layer of water, there then appears darker than the rest.

Cornell University. W. P. White.

BIOLOGY.

There would seem to be a great many interests which the teachers of biology have in common, and this interest might even extend to those sciences that touch this more or less. They all have common ground in "methods of teaching," especially to encourage individuality of method in the teacher, so long as it is good method, laboratory method, and productive of sound results. Of much importance to the teacher should be the *aims* of courses in biology. Given in the order of importance, these might be put in the following way: Preparation for college, getting

ready for some profession, general culture and training for better living. Of these, the larger schools have in recent times paid much attention to college entrance requirements. In many cases this was quite logically settled in botany by the corresponding college departments accepting the work done by teachers of their own training. Not so with the college teacher of zoölogy. He does not like to see the broad training given his students by him, returned in abridged form, sated with the wonders of biology. In some cases he has treated the high school efforts with more indifference or contempt than approval, but in most cases the college authorities have adjusted the matter for the present by prescribing largely the nature of the course. In this there has been a return toward the old-fashioned natural history method, and more lately toward general external study of animals and field work.

The high school teachers have not yet asserted themselves as to the nature of the course they think best, so that the courses are at present mostly either the result of their training or of college legislation. A fundamental error has crept in on their side; it is that both they and the high school graduates seem to expect advanced standing in college for work done in the high school.

On the other hand there are few college teachers who appreciate the difficulties in the way of the high school science teacher in the lower grades, say the second year, where the biology is generally taught. Their efforts to simplify this kind of work have been to condense their learning into short sentences or a kindergarten method of expression, both of which fail with the high school student of average intelligence. Nevertheless, it is desirable to have full and free expression from the college teachers as also from those who bear the burden. Full discussion of these matters by both sides is the desideratum, and the high school teachers might begin by short expressions of their views in these columns. Correspondence along this line is especially desired.

While on the one hand teachers are urged to teach the history of their science, there are also many advocates of the teaching of the economic side of biology. Many teachers get the bulletins of the various state Agricultural Experiment Stations, and those from Washington. There is a regular "Monthly List of Publications" sent out from Washington to all who apply for it.

Somewhat in this line is *"A First Book on Forestry,"* by Prof. Filibert Roth, Chief of the Division of Forestry, U. S. Department of the Interior, published by Ginn & Co. The *American Naturalist* (July) says of it: "The little volume is intended for use in the public schools and in country homes, and gives in non-technical language an exceptionally clear and readable account of some of the significant aspects of forest life and growth, the most important principles underlying the practice of forestry, and the methods now employed in such common forestry processes as thinning the wood lot, seeding for succession, sowing cleared areas, etc."

The loan of collections of invertebrate specimens to as many of the public schools of greater New York as make proper application, has been arranged by the American Museum of Natural History. (SCIENCE, June, 1903). These are especially for use in connection with the teaching of biology, not nature study, we understand.

A lamp lighted by means of bacteria (SCIENCE, May, 1903) has been reported by Professor Hans Molisch. "The lamp consists of a glass jar, in which a lining of saltpeter and gelatine inoculated with bacteria is placed. Two days after inoculation the jar becomes illuminated with a wonderful bluish-green light caused by innumerable bacteria which have developed in time." This reminds one of the glasses full of fire-flies that south-sea islanders are said to carry for lanterns, or the glass full of tropical phosphorescing pelagic organisms that Haeckel tells us serve for reading a letter or newspaper.

Under "Possible Use of Radium," (SCIENCE, Sept. 11) Sir Albert Lodge characteristically says "it is held in great estimation by physicists who see in its amazing energy possible solutions for old problems and materials for new ones!

That there is any analogy between its rays and those of luminous insects would, in any case, be doubted by those who hold that the light emitted by the insect is a product of metabolism.

L. M.

Preserving Butterflies in Plaster of Paris.—The butterflies should first be pressed on the pressing board, no pin being put through the body. Plaster of paris is then mixed with water and spread on the glass which is to cover the butterfly. The mixture should be thin enough to spread easily, yet thick enough to keep its shape. The thickness of the layer varies from ½ to ¾ inch, depending upon the thickness of the insect's body. When the plaster has set it can be loosened around the edge and slipped from the glass. A groove large enough to contain the body of the butterfly is cut with a penknife in the smooth surface of the plaster of paris, the butterfly, which has been relaxed again, is laid in position, the glass and the pasteboard back laid on, and the edges secured by binding with white passe partout paper. As waste negatives can be obtained of a photographer for little or nothing and plaster of paris is only 2 cents a pound, the expense is very slight, and a little care about putting the insects in when the plaster is very wet or when the insects have been exposed to museum pests will make the collection permanent. If both sides are desired, two specimens, one showing the reverse side, may be mounted under one glass. Dragonflies are easily mounted in the same way.

Morrison (Ill.) High School. HELEN A. SOUTHGATE.

Reports of Meetings.

NATIONAL EDUCATION ASSOCIATION—SCIENCE SECTION.

At the forty-second annual convention of the National Educational Association, two morning sessions were devoted to science. On Thursday, July 9, 1903, the subjects of geology, geography, biology, and physiology were considered, and on Friday, July 10, the entire time was devoted to chemistry and physics. The meetings, which were largely attended, were under the immediate direction of the officers of the section, President C. W. Hall, Minneapolis, Minn., Vice-President Wilbur A. Fiske, Richmond, Ind., and Secretary Frank M. Gilley, Chelsea, Mass. Through the courtesy of the officers and the daily press we are able to present to the readers of SCHOOL SCIENCE a complete account of the meetings. The order of the papers in this report is the same as that given in the official program. Owing to space limitations we are reluctantly compelled to publish condensations of all papers except two.

1. *Practical Methods in the Teaching of Geology.* NATHANIEL S. SHALER, Professor of Geology, Harvard University. Professor Shaler said that although he had taught geology for nearly forty years, his work had been almost entirely with college students, most of them fresh from the secondary schools and in temper and quality not greatly different from those to be found in the ordinary high schools and fitting schools. What success he had had, he said, was due to the fact that he very early cast away all idea of following the methods adopted by anybody else, excepting to throw himself with his whole soul into his work.

Geology, he said, consists of the application of practically all the other natural sciences, and for this reason it ought not to be taught to very young pupils. The student who does not bring with him to the study of geology some glimmer of knowledge of these other natural sciences, especially chemistry and physics, is not ready to appreciate geology. This would place it not earlier than the last year in the high school.

His own experience, by which, through a combination of circumstances, he began to acquire geologic knowledge at the age of thirteen, showed the ill effect of trying to teach geology too early. He had found himself struggling to obtain the knowledge he craved, and had learned much of it wrong. This resulted in his gaining conceptions regarding geologic phenomena which had stood in his way and troubled him even to the present day.

"We need to bring the child to the conception of the earth as alive," said Professor Shaler. "Keppler has been laughed at for his conception of the earth as a living being with a heaving bosom; but Keppler was not far from right in his conception, and was far ahead of that trail of the serpent across our modern study of geology—the idea that the earth is dirt.

"I have tried to have my students associate the earth with their fellow-life. In this I found it of advantage to take up first the study of water, showing the changes of the earth through the action of water, as if it were a water mill with a sun motor. Keep out of your teaching the recondite matter. Keep out the names. The child will be stunted in its comprehension if you burden him with the technical names associated with the subject. Keep the living aspects of the subjects before the child and remember that those aspects are most vivid which concern man."

2. *The Proper Scope of Geological Teaching in the High School and Academy.* WILLIAM NORTH RICE, Professor of Geology, Wesleyan University, Middletown, Conn. He said in substance:

"Several recent reports on the high school curriculum seem to indicate a consensus of educational opinion in favor of a required course in physical geography in the first year, and an elective course in geology in the fourth year. This is probably the best arrangement.

"The course in physical geography thus precedes the bifurcation of the curriculum into classical and non-classical, and is a most desirable study for all. That it should become a part of the requirement for admission to all college courses is a consummation devoutly to be wished.

"This course should be shaped substantially in accordance with the report on physical geography presented to the N. E. A. in 1899.

"The course in geology will be in some sense an amplification of one part of the course in physical geography. While the subjects treated in physical geography and geology are in part identical, there is always a difference in the point of view. Geography has been said to be the study of the earth's present in the light of its past; geology, the study of its past in the light of its present. The recognition of the earth's history is incidental in geography, essential in geology. Dynamical and structural geology gives the key to the alphabet in which the earth's monumental inscriptions are written. Historical geology reads those inscriptions themselves. Something of dynamical geology must, of course, be implied in any other than a purely phenomenal description of geographical facts. But the dynamics of the globe, which can only be treated superficially in the first year, can be treated much more thoroughly in the last year, after the study of physics and chemistry and perhaps of other sciences.

"The high school course in geology should be chiefly a course in dy-

namical and structural geology. No one course indeed is best for all schools. Something must depend upon local conditions, something upon the qualifications and idiosyncrasies of the teacher. The students will generally not have had enough of zöology and botany to do much with paleontology. Mineralogy and lithology can not be thoroughly studied without crystallography and without more of chemistry than can be assumed. In general, a non-technical description of a mineral is an incorrect description.

"The characteristic educational value of a course in dynamical and structural geology is as a training in scientific reasoning. The question which should be emphasized is, how do we know that the earth has had a history? What are the signs by which past changes are inferred, and what is the ground of validity of the inference? Dynamical geology is sometimes introduced before structural, sometimes after. The former arrangement seems better adapted to initiate the student into the thought of interpreting the phenomena of the earth's crust as evidence of former changes. In my own lectures I have followed what seems to me a still better plan—that of mixing the dynamical and structural geology, so that each particular class of rocks or of rock structures is studied in immediate connection with the discussion of the agencies to which it is due.

"Most schools are supplied with at least small collections of rocks and minerals. Even more important, though generally not provided, are specimens illustrative of processes in dynamical geology. And no museum, however complete, can take the place of excursions in the field."

These papers were discussed by Professor Niles, of the Massachusetts Institute of Technology, who urged the importance of teaching geology, on the ground that it gave a nobler mental training than chemistry and physics in themselves. He also urged the gathering of facts in such way that they would result in grand conceptions of the earth's decelopment.

Mr. A. G. Clement, of the Board of Regents, New York, said that in New York the physical geography teachers had found great help through numerous field excursions and the making of weather maps.

3. *Outdoor Class Work in Geography.* F. P. Gulliver, St. Mark's School, Southboro, Mass.

"There are two methods of conducting science work out-of-doors; one of these is the field excursion, and the other the field exercise. A large number of pupils can go on an excursion, while only a small number, ten or fifteen, may profitably take part in a field exercise.

"Both methods tend to increase the observational faculties of the pupils. On an excursion the instructor may point out many geographical features, and thus show the pupils what to see, and the forms which have been studied in the classroom may be pointed out to the students, and other forms shown which may later be taken up in class. As many

as can hear the instructor may gain information from this method of field work.

"In a field exercise, on the other hand, only a few may take part. The instructor must see that each student understands each point in the exercise before the next is shown. A few facts are given, and the pupils must work out others from their individual observation. This is the laboratory method carried into field work. The pupil is taught to observe, record, explain and predict."

The contrast of these two methods of field work was discussed in this paper, bringing out the advantages and disadvantages of each. Several examples of field exercises were given from those in use at St. Mark's school, among them being the following: A series of exercises on glacial deposits, one on river valleys, and another on shore-line forms.

4. *The Teaching of Biology in High Schools.* A. S. PEARSE, High School, Omaha, Neb. He said that biological work is usually placed in the second year in the high school course, though he himself felt that it should be in the last year. The course ought to consist largely of laboratory work and should cover as long a period as possible, on account of the fact that very few of the pupils will continue the study thereafter. He found it advisable to have field expeditions and collecting expeditions. These serve to fix in mind forms which it is desirable to recognize. The ability to recognize is expected rather than a large collection, and the speaker requires that certain specified obtainable forms shall be collected and either mounted or preserved. He is accustomed to give an option on collecting either native woods or native leaves, all mounted, labeled, etc. Drawings made by pupils ought to be shown to the teacher for criticism in order that the student's progress may not be long impeded by a wrong conception of some fundamental form. The speaker said he had circumvented the unsatisfactory use of a text book by using a series of mimeograph sheets prepared by himself, in which questions and information were given out, and which he called "study schedules." The course in a high school ought to deal primarily with the fauna of the district in which the school is located.

5. *Laboratory Teaching of Physiology.* DR. W. T. PORTER, Associate Professor of Physiology, Harvard Medical School.—This is a modern subject, he said, like embryology; although anatomy is older than the pyramids. Anatomy has had a great influence on physiology, and for many years the two subjects were considered in the medical school together. Physiology was "split off" from anatomy, and its teaching followed for a time the old-fashioned lines followed in anatomy, largely from a text book. The practical difficulties in laboratory physiology were very many and costly.

Physiology is not a descriptive science; it can not be committed

to memory; it is not a fixed state and can not be tabulated as a permanent thing at any one moment. Words will not serve to describe the passage of a contraction wave over the heart, for instance. At present the medical school divides the physiology into small groups; selects a few fundamental experiments, of which the student does one or more in each; then the student afterward looks up his authority in text books, and related observations are tacked on to this fundamental experiment.

The experiments which form the real foundation of the subject are arranged in logical sequence, but the student always does the experiment before going to the books. Everything is now based on these experiments instead of on the authorities. The class does much of the teaching. It is divided into committees of eight, with a chairman chosen for his special ability, and thus the more skillful students assist the others. The students also by means of theses from the original sources take part in the didactic teaching.

The medical school is trying to promote this new method all over the world. It has succeeded in reducing the cost of many pieces of apparatus several hundred per cent as for instance from £5 to $1.50, or from $150 to $16. Catalogues of the apparatus now available will be sent on request.

6. *Laboratory Teaching of Physiology.* JAMES E. PEABODY, Morris High School, N. Y.—An abstract of Dr. Peabody's paper follows:

"Physiology has not hitherto had an honored place in the school curriculum, because anatomical details or the dry rules of hygiene have been too frequently emphasized, rather than the interesting and profitable principles of physiology; the subject has often been taught by teachers who have not made a specialty of biology, and physiology, in the minds of too many pupils, is synonymous with instruction as to the effects of alcohol and narcotics.

"This view, however, is not the one that should be held, for it is easy to interest boys and girls in the functions carried on in their own bodies. It is important for their health and happiness that they know how to care intelligently for the organs of these bodies. An intelligent public sentiment respecting sanitation, street cleaning and the work of boards of health can be best developed by a proper teaching of physiology, and this subject, when taught by the laboratory method, has real educational value.

"Some knowledge of the facts of chemistry is essential if physiology is to be taught at all satisfactorily. For first-year pupils, therefore, the course should begin with simple experiments to show the properties of elements and compounds and the processes of oxidation and neutralization. Food analysis should follow, and the tests for starch, sugar, fats, proteids and mineral matter may be carried on at home by the individual pupil. In the study of the uses of food, the cooking of foods and food economy, the publications issued free by the United States Department of Agriculture may well be used.

"Laboratory exercises in the study of sheep bones and beefsteak help tc familiarize the boys and girls with a half dozen of the most important tissues found in the body. Reference should frequently be made to cells and their functions. Most of the important facts that relate to the skeleton, muscles, skin and sense organs can be acquired by observation and experiment. In all cases text book lessons should follow and supplement the work in the laboratory.

"A considerable amount of supplementary work should be done in a course in human physiology. At the parks and museums pupils are much interested in studying the skeletons and teeth of various kinds of animals, their food and feeding habits, their methods of locomotion and the ways in which they are protected from their enemies. Especially important is the laboratory study of bacteria that can be carried on in the high school. Pupils should be taught the methods of cultivating and of killing these micro-organisms, the benefits they confer upon mankind and the many ways in which they are injurious. Especial emphasis should be laid on the principles of sanitation and the work done by the board of health.

"All this work and much more can be done in half-year course of five periods a week. That the laboratory method is much to be preferred to mere text book recitation is evident from the interest manifested by the pupils, from the greater clearness with which they express the facts they have learned, and from the ease with which these facts can be brought to mind when needed, even after the course is completed. Much remains, however, for the teachers of physiology to accomplish, both in the selection of the important topics to be taught and in the development of successful methods of teaching."

7. *College Chemistry and Its Relation to Work Preparatory to It.* Ira Remsen, Johns Hopkins University.—President Remsen spoke from brief notes, and the following is an abstract of his remarks:

"College courses should be elementary even in the case of those students who have had a preparatory course in a high school, for it is impossible to give the student clear ideas without going over the subject, no matter how good the student or how good the teacher. It is with chemistry as with other subjects: repetition is necessary. How much English or Latin, or any other language, can be taught in a year one hour a day?

"One reason why language courses are so valuable pedagogically is that they involve so much drill. Day after day, year after year, the same general conceptions are dealt with and illustrated by new examples, until finally these conceptions become a part of the mental equipment of the student. The mind has received lasting benefit. On the other hand, in chemistry every day brings something entirely new and not clearly connected with what has gone before. The student can not take any clear ideas with him. If my experience is worth anything, he rarely does, even after a year's work. He has had too many impressions. He knows about as much of chemistry or chemical phenomena as he would of a language if

he had spent a year in studying its grammar and had tried to read a passage from a different author every day. No matter who the student, or who the teacher, a year's course in chemistry can not do very much for a student. Most of the work will have to be done over again in some way if clear ideas are to be gained. Nevertheless this work is valuable, as it prepares the mind for subsequent work.

"The ideal course in chemistry has not yet been worked out. Indeed, I am not sure that there is an ideally correct course. I fancy that it would be well for a student to follow different kinds of courses, so that he may look at the facts and the principles from different points of view.

"In an elementary course, whether in high school or in college, I should like to see the facts emphasized, and I should always try to connect the work of the day with the experiences of everyday life. This is, I believe, sound pedagogics. It is certainly sound sense.

"Theory, in my opinion, should play a subordinate part in elementary instruction, though I do not feel that it should be excluded. The atomic theory is meaningless to one who knows nothing of the facts, and it means little to one who knows little of these facts.

"Professor Agassiz said, and I am sure thinking teachers will agree with him: 'One can see no farther into a generalization than just so far as one's previous acquaintance with particulars enables one to take it in.'"

8. *High School Chemistry in Its Relation to the Work of a College Course.* Rufus P. Williams, English High School, Boston, Mass.—Mr. Williams said:

"This paper attempts to show not only the relation which exists between high school and college chemistry, but that which ought to exist. The elements of chemistry should be taught by the same method, whether in preparation for college or for business, just as elementary arithmetic or reading is taught by similar methods to persons destined for different spheres in life.

"The persons best qualified to judge of the subject matter and methods most suitable for admission to college are not, as formerly supposed, college professors, nor, on the other hand, high school teachers. Decision should be made by mutual conference of the two classes of instructors. The one class may know more about the objective science, the other is better acquainted with the subjective attitude of the boy's mind, the latest fads not being necessarily the best in all points.

"The college entrance examination board is now the greatest factor in the closer articulation of high school and college work as regards chemistry. It has given three examinations and only one college in the United States has refused to accept its papers. Mr. Williams has obtained replies from twenty-three colleges and universities to the effect that in almost all of them the elements of chemistry must be repeated in college, even if the student pass the searching entrance examination, before he can go on with more advanced chemistry. This, he reasons, is a great waste of time and unwarranted. The colleges say that the chemical student from the high

school is most of all deficient in a comprehensive understanding of laws, theories and general principles and their application.

"The high schools are attempting to crowd too much chemistry into one year, and are doing too little. The latest improved theories of physical chemistry and all the rest are given in homeopathic doses before the pupil has a working knowledge of those of Dalton or Avogadro. Entrance examinations are set for a crammed one-year course and the work must be repeated in college.

"The remedy is either to insist upon at least two years' thorough teaching of general principles, nonmetallic and metallic elements, or to limit the work to one year, if necessary, and drop out the consideration of metals. In either case insistence should be on such thorough work that no repetition be needed. An earnest plea was made that a conference of college and high school teachers formulate a plan to avoid the loss of a year in the study by repeating preparatory work in college."

9. *Chemistry from the College Standpoint.* H. P. Talbot, Professor of Analytical Chemistry, Massachusetts Institute of Technology.—He said in part:

"The increase in numbers in the secondary school renders it more and more difficult to adequately provide for pupils with varying aims. Since the majority of the pupils of such schools is made up of these who will not enter upon college work, the question may fairly be raised as to what sort of instruction is best for this large class of students, and whether such a course may also be found suitable as a preparation for college work.

"For the pupil who will not pursue the study of chemistry further, that course may be assumed to be the best which will contribute most to his general information and culture by acquainting him with a wide range of chemical facts, while at the same time it trains, by means of laboratory practice, his power of observation, and his capacity to associate conclusions drawn from a given set of observations or data with those already within his knowledge. Such a course should include the fundamental principles of the science, but not the more complex principles or theoretical conceptions. It demands a teacher who is well informed, who takes pains to discourage the mere memorizing of facts, and at the same time stimulates curiosity and interest, guides the student in the laboratory, correlates the various parts of his instruction, and emphasizes the principles which he teaches by copious applications.

"With such a teacher in command, this course should also serve acceptably as a foundation for college work. The college instructor can with this as a basis, and with the advantage of added maturity of the student, develop the more advanced principles and theories of the science, with confidence that the student will be capable of drawing upon his own fund of knowledge for instances in which these abstract conceptions find application. It is not contended that no differentiation should be made between the work of pupils destined for college and those less fortunate, but rather

that this differentiation need not be so marked, as it often is at present, nor go so far as to entail a decided burden for the teachers.

"The teaching of chemistry in the secondary schools has a tendency to include too much, especially of 'theory,' when the mental immaturity of the pupil is taken into consideration, together with the time allotted to the subject. Every teacher should make all possible effort to keep himself well and broadly informed, but should be sure to limit his instruction to the capacity of his class, holding himself ready, however, to stimulate and instruct the exceptionally thoughtful and progressive pupil."

10. *The Laboratory, the Place to Teach Fundamental Principles.* LYMAN G. SMITH, President of the New England Association of Chemistry Teachers, Boston, Mass.—Mr. Smith gave a lucid account of his own experience, which will be published in full in a forthcoming number of SCHOOL SCIENCE.

11. *Chemistry Teaching: The City Superintendent's Point of View.* WILLIAM F. KUNZE, Superintendent of Schools, Red Wing, Minn.—Mr. Kunze's abstract follows:

"The high school has for its object the preparing of its pupils for the activities of life and for the higher institutions of learning. To arrange the high school course so as to articulate with the needs of active life and the entrance requirements of colleges is the problem the city superintendent has to solve.

"Chemistry has now been generally conceded a place and rank in the high school curriculum, but its limitations and mode of presentation are still much mooted questions; consequently there is a deplorable lack of unity in the aim and method of teaching chemistry. This state of affairs is due very largely to the colleges and universities. Their courses of instruction are widely divergent, and their entrance requirements are far from being uniform and definite. The instruction given in the colleges to those who expect to teach is in most cases identical with that given to those who intend to become chemists and analysts.

"The teacher of chemistry needs less technical knowledge, but a more thorough understanding of general chemistry. He must be imbued with a spirit of investigation. Furthermore, he should be able to point out the far-reaching relations of chemistry to commerce, industry and daily life. In short, he should see to it that chemistry is the means of making the school life touch the real life at as many points as possible. We are hampered in not being able to secure enough properly qualified teachers of chemistry.

"The universities must come to the rescue and contribute their share to the solution of this problem, not by fixing uniform or hard and fast entrance requirements, but by devoting their energies to the task of furnishing us well qualified teachers. With a supply of good teachers, the city superintendents will soon answer the question, What should constitute a

high school course in chemistry? When that has been accomplished, the matter of entrance requirements will take care of itself; but until that is done our high school work in chemistry will continue to be vague, haphazard and aimless."

12. *The Normal School View of Chemistry Teaching.* LYMAN C. NEWELL, Ph. D., Normal School, Lowell, Mass.—An abstract of Dr. Newell's paper follows:

"The function of the normal school is to prepare its students for work as teachers in the public schools. In some normal schools the instruction anticipates teaching in the high school, but the majority of normal schools confine their instruction to students who eventually teach in the primary and grammar grades. It is this type of school that the speaker has in mind.

"Chemistry occupies a unique position in the curriculum of the normal school. Like algebra, geometry, and psychology, it is seldom taught as a distinct subject in the grammar schools, but, unlike mathematics and psychology, it has a direct bearing on several subjects which have a fixed place in the course of study of the grade schools. Such subjects are physical and commercial geography, physiology, hygiene, and nature study. Indeed, certain parts of these subjects are chemistry pure and simple, while the interpretation and application of other parts are largely measured by a teacher's knowledge of chemical facts and principles.

"Sufficiently pursued and properly supervised, chemistry provides a large share of that element so essential in successful teaching, *viz.*, an inherent tendency to observe and consider all the facts before pronouncing a final judgment. Too often the teacher confuses fact and theory simply because no opportunity has been taken to learn to discriminate between the two. This contribution of chemistry to the equipment of a teacher is so intangible that it is often overlooked in normal school work, but its vital importance can be scarcely overestimated. To see the truth and be convinced by it, to distinguish with certainty the best in the midst of the inaccurate, and to draw unerring judgments—these are invaluable adjuncts to the qualifications of a teacher.

"The problem of the normal school teacher of chemistry is to furnish a material which shall not only contribute the needed information, but also provide that training needful for the success of the future teacher. The work, to be effective, must be a combination of utility and scientific training. It is wrong to assume that if a young teacher has only facts, she will in some mysterious way speedily acquire the ability to use them efficiently, or, on the other hand, if she is only subjected to training, it is of little moment when, where, or how she secures facts. Both assumptions are pernicious. The aim in all normal school instruction, particularly in experimental science, is to provide work which will yield information and training simultaneously.

"An effective course in chemistry in a normal school will center around

certain broad topics, *viz.*, air, water, carbon, acids, alkalis and salts, sulphur, and the important metals. These topics, with their numerous subdivisions, furnish abundant material for work in both classroom and laboratory. An experience of several years shows that it is possible to include in such a course a study of the elements—oxygen, hydrogen, nitrogen, carbon, sulphur, chlorine, sodium, potassium, iron, lead, copper, zinc, and their important compounds. A course of this kind can be so arranged as to cover such important topics as the function of air and of water in nature, the cycle of carbon, the manufacture of acetic acid, alcohol, soap, sugar, starch, sulphuric acid, lime, common salt, and ammonia, the iron and steel industries, the role of carbon dioxide, the decay of animal, vegetable and mineral matter, and the manufacture of metals from their ores.

"It is the speaker's conviction that laboratory work should occupy the greater part of the time devoted to chemistry. Facts gleaned from books are fleeting, but when they are driven home by actual verification, they become permanent knowledge. Take, for example, the composition of air. The student reads in a book that it contains one-fifth oxygen and four-fifths nitrogen, but these proportions are apt to be transposed, indeed, they often are in examination papers. But when the student finds in the laboratory by personal labor that a given volume of air actually does consist of one-fifth oxygen and four-fifths nitrogen, the proportions will not be forgotten, especially if the experiment has involved arithmetical calculation. This experiment, often regarded as too difficult, can be accurately and rapidly performed with simple apparatus.

"The laboratory work in chemistry must undergo constant inspection and modification by the normal teacher, so that the student will unconsciously acquire a willingness to observe all the facts with patience and precision and to accept as truth only those conclusions which are the outcome of logical deduction from facts."

13. *Aim and Scope of High School Chemistry.* Albert S. Perkins, High School, Dorchester, Mass.—Mr. Perkins said in substance:

"Not only the high school of today, but of the future as well, is to be considered, as it is by no means improbable that the German system may prevail in our country, the high school taking the place of the gymnasium.

"The condition which confronts the high school chemistry teacher is most humiliating, practically no higher institutions providing a second course for those who have studied chemistry in the high schools. The causes are lack of harmony among secondary chemistry teachers as to what subjects should be taught, lack of thoroughness and too great conservatism in adopting modern ideas. The old high school chemistry is too simple both in its subject matter and in its methods. It is not enough to commit to memory facts, no matter how important, and illustrate these by individual laboratory work and lecture demonstration. Everything should be made a problem, a research. Facts memorized are of little value, the scientific spirit is everything.

"The aim and scope of this new high school chemistry should be: First, thoroughness. The work should not require repetition in the college. Secondly, the course should be inductive, everything beginning with the pupil's own work in the laboratory, supplemented by lecture demonstrations, quizzes, recitation, text book and reference book work. Thirdly, receptiveness on the part of the teacher to modern thought. The 'law of mass action' and the 'electrolytic theory' should be fundamental principles of the course. The pupils will understand modern ideas if the teacher understands them clearly himself. Both qualitative and quantitative experiments should be performed according to the subject studied.

"The sole aim of such a course is to teach boys and girls to think along scientific lines; but many facts are incidentally acquired. The pupil will be amply able to begin qualitative analysis, which should constitute the second course. This course is best for the noncollege boy, the college boy and also for those entering technological and medical schools, since its purpose is to make pupils think along scientific lines, and since in the accomplishment of this purpose the most important facts and principles of the science are acquired."

14. *Physics for Boys and Girls: An Introductory Course.* J. C. PACKARD, High School, Brookline, Mass.—He said in part:

"We are living in an age of applied science. What effect is this tremendous fact producing at the present moment upon the courses of study in our schools and colleges? Our institutes of technology are flourishing as never before. Manual training schools are springing up with the greatest rapidity all over the country. The number of students enrolled in the scientific and technical courses of our correspondence schools is reckoned by the hundred thousand. But—and this is the significant fact—the physics of our secondary schools, to say nothing of the chemistry and the biology, is steadily giving way to such old time subjects as Latin and algebra.

"What does it all mean? I can only hint at a partial reply. The miracles of science are all about us. The school boy, intensely interested, comes to our laboratories with a thousand eager questions about dynamos, motors, x-rays, telephones, electric lights, wireless telegraphy, submarine boats, automobiles and a host of similar things, pressing for an answer. What is the result?

"In too many cases he is introduced at once to the difficult subject of exact measurement, required to make immediate use of such unfamiliar instruments as the diagonal scale, the vernier caliper, and the balance sensitive to a centigram; to report his results in terms of the metric system; to discuss errors, sources of error, percentages of error, averages and probabilities; to deduce laws, many of which he knew before, from data that can not be made to prove anything, and to apply these laws to a set of problems that have no apparent relation to his immediate scientific environment, or to the question that he is so anxious to have answered. What wonder that the boy so often becomes discouraged and that physics ceases to be attractive.

"We must teach principles, but we must keep these principles in close touch with their applications. Illustrated lectures upon the applied science to be found in our schools, our streets, our houses and our factories, with just as much of the human element as can possibly be introduced, together with extracts from periodicals containing bits of the latest scientific news, should be a vital part of every course for beginners in physics. The method of research is not the method for the immature mind.

"Skill in manipulation of apparatus with a development of the 'habit of mind' belonging to the 'scientific method' may be the primary objects of instruction in our own mind, but they are side issues when viewed from the standpoint of the average boy. We must be content to attain these higher ends gradually as a final, not immediate, result. We must remember, moreover, that interest is our greatest lever.

"With these ideas in view we have introduced into our own school a course of applied physics, in which the laboratory waits upon the lecture and the discussion, intended for the average boy and girl who does not expect to go to college. Pupils preparing for Harvard pursue a distinct course by themselves. The arrangement has worked well. We should be glad if each pupil could be given an opportunity to take both courses, but this is impossible in the present crowded state of our curriculum."

15. *The High School Course in Physics.* Irving O. Palmer, High School, Newtonville, Mass.—Mr. Palmer's paper will be published later in School Science.

16. *The High School Phase of Physics Teaching.* George R. Twiss, Central High School, Cleveland, Ohio.—An abstract of this paper follows:

"John Tyndall insisted that physics should be used not as a branch but as a means of education. Instead of trying to teach physics we ought to try, through the teaching of physics, to help in educating boys and girls into a broad and efficient manhood and womanhood. The purposes of physics instruction are: The development of power, ability to compare, to reason from known to unknown, to judge; the creation of an atmosphere favorable to general culture, training in clearness and conciseness of expression, instruction in practical knowledge, inculcation of the love of truth for its own sake.

"Physics should be taught, not as a collection of miscellaneous facts, but as a body of organized truth, logically connected throughout. Lectures, recitations and laboratory work should be so connected that the student may progress by a series of firm steps from familiar ground to a new and a higher standpoint, from which he can get a wider view of the field.

"The best training is given and the greatest interest excited by guiding the pupils through a series of mental operations similar to those by which great discoveries have advanced, *i. e.*, observation of phenomena, formulation of a hypothesis to explain or generalize observed facts, deduction of particular facts that must follow as a consequence of the hypothesis,

verification of the hypothesis by experimental tests of the consequences thus deducted. In these tests, effects other than those to be tested are excluded or corrected.

"Recitations should be by topics, and each pupil should be subjected at the end of his recitation to a cross-examination, which serves to clear up obscure points and fortify conclusions. If badly conducted it will obscure and discourage, but if successful, the student will critically examine the grounds for his opinions, and will possess stronger confidence in the uniformity of natural laws and processes and in his ability to judge facts and draw conclusions. In effect it should be constructive, not destructive; positive, not negative. The unity of the recitation plan should be preserved.

"Laboratory exercises should have the following characteristics: They should compel close observation and discrimination, develop skill and self-reliance; there must not be so many things to observe as to cause mental confusion; each should contain the basis for generalization or verify a principle previously deduced; the reasoning must lead simply and directly to the conclusion; the manipulations must not be too difficult; each must be susceptible of respectable accuracy, and the results mainly such that their accuracy may be judged by comparing them with one another rather than with those given in books; there must not be so many operations that they can not be completed in the time allowed; there should be a sufficient number so that when supplemented by the lecture demonstrations the main outlines of the subject shall rest back upon experimental work or deductions therefrom."

17. *A Course in Physics for Technical Schools.* Charles F. Warner, Principal Mechanic Arts High School, Springfield, Mass.—Mr. Warner said in substance:

"It is self-evident that in high schools where mechanical work is required of all pupils there is for both boys and girls, but especially for boys, immediate and constant application of the fundamental principles of physics.

"It follows from these relations that the teaching or physics must be more thorough and practical than is commonly the case in high schools, and it must be brought into closer correlation with the work of other departments, especially with drawing, shop work and mathematics. This will require, first, that much more time be given to the teaching of physics than is commonly given to it in high schools; second, that the study of physics should be begun the first year and not delayed until the third year, when more than half of the rich opportunities for illustration and application afforded by the mechanical departments of the school have been left behind; and, third, that the course of study and the methods employed should vary from those which are obtained in other high schools. In the technical high school several text books, instead of one, and a reference library, are indispensable, and the student should be taught the use of

scientific apparatus of a kind actually found in the various arts and industries.

"A peculiarity of technical high schools is found in the fact that they are usually for boys only, and even when open to both sexes the proportion of boys is larger than in other high schools. This means much in determining the extent and character of the course in physics, which is pre-eminently a study for boys.

"In technical high schools there should be a four years' course in physics. It should be a required study for the first two years and elective for the last two. During the first two years the entire subject should be covered in as thorough a manner as possible. The last two should be devoted to quantitative measurements and special applications in applied science."

Reported by LYMAN C. NEWELL.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS—BIOLOGY SECTION.

The meeting was held at the Armour Institute of Technology, in Chicago, April 10 and 11, 1903. After a short business session at 2 p. m. on April 10, the section joined with the physiography section to listen to an interesting and suggestive paper by Dr. Henry C. Cowles, of the University of Chicago, on "The Influence of Plant Life Upon Physiographic Forms." After the paper the section reassembled and several short talks were given under the general head of "Tricks of the Trade."

Dr. Fred B. Maxwell, Chicago, described a rapid method of making lantern slides, consisting in drawing upon a glass plate with a fine pen, using India ink or colors, and covering with the usual cover glass.

Dr. H. S. Pepoon, Chicago, recommended for the preservation for years of specimens of fern fronds, lichens, etc., mounting them on cardboard and covering with glass, or mounting them between two glass plates, the edges being fastened together with passe partout paper.

Mr. F. C. Lucas, Chicago, called attention to a somewhat similar method employed in studying the wings of insects. It consists in putting the wings between two slides and fastening them with rubber bands.

Mr. C. H. Robison, Oak Park, Ill., suggested the comparative study of poison ivy and the Virginia creeper. He uses Hazel jars and puts specimens of each plant in the same jar. He also suggested that in studying the effect of removing the cotyledon of a seedling the cork in which the seedling is fixed should be floating in water. Dr. Pepoon stated in this connection that poison ivy could probably be handled in winter without danger, as over a hundred of his pupils had done so, without ill effect.

Mr. E. M. Williams, La Grange, Ill., described a method of making lantern slides without making a positive, copies of pictures in books being readily prepared. Any cheap plate is treated with a 5 per cent solution of

potassium bichloride and washed. The exposure is from four to five minutes. The plates thus prepared must be used within a week.

Mr. H. E. Walter, Chicago, uses, in the study of bird skins, boxes made from molding, old photographic negatives (carefully cleaned) being taken for covers. The bird is fastened to two crossed wires, and the glass attached to the box by means of black gummed paper. Mr. Walter also showed insects mounted in similar cases.

Mr. W. W. Whitney suggested that pictures (without explanations) be cut out of old books and mounted on strawboard, to be used for review exercises. He thought it would be a good plan to mount in the manner suggested by Dr. Pepoon, leaves, stems, etc., collected during the summer time.

Mr. Walter showed a system of weekly bulletins made upon the mimeograph and given to each pupil. He claimed for the system a saving of time and a gain in accuracy.

Mr. E. E. Hand, Chicago, suggested the use of old magazine articles, to be bound in covers similar to those of the note book, and that a library of such articles be gradually accumulated. He emphasized the advantages of the plans indicated by previous speakers of having permanent material fixed so that pupils could not injure it.

Mr. A. H. Conrad, Chicago, showed some lantern slides intended, among other things, to illustrate biography. He suggested the desirability of saying something about the zoölogists and botanists in connection with the group being studied. He requires a certain number of biographies from his pupils.

Mr. T. J. Heodler, Rensselaer, Ind., urged that, as far as possible, pupils collect their own material; that to be used later in the year to be collected in the fall and preserved until wanted, each pupil to have his own collection. He believed that through this individual work the interest of pupils is greatly increased.

Mr. W. R. Mitchell, Chicago, urged the formation of science clubs among high school pupils, in the meetings of which parents and others could participate.

After some general discussion as to projection instruments and as to the feeding of turtles, etc., during the winter while kept in the laboratory, the meeting adjourned for the day.

The section met again on Saturday, April 11, at 10 a. m. The following officers were elected: Chairman, Dr. Fred B. Maxwell; secretary, Frederick C. Lucas; member of executive committee, H. A. Frazier.

The first paper was by Prof. C. R. Barnes, of the University of Chicago, on "Plant Physiology in Secondary Schools." In the discussion that followed Dr. Maxwell remarked: "In classes as large as we have it is almost impossible to have individual experiments by the scholars. It is hard to get the material and to give the time necessary."

In reply Dr. Barnes said: "I think an ideal condition is to have each

pupil do every experiment of the course. I should always put two students to work together. There are many cases where one would have to have more than two hands to set up the apparatus, and if one can not secure the conditions where it is possible to have two students work together, I would have three or four, or even five, but never more than five, on one experiment. Then at certain times I should have the matters discussed and the results of the experiments shown. General experiments should be done by the teacher. The smaller experiments should be done by the smallest number of students that can assist under the conditions."

The question was raised, "What can be done with a class of forty to take care of at once?"

Dr. Barnes replied: "Divide in two sections, or, if possible, in five sections of eight pupils each," and in response to the question, "Would you recommend a course in plant physiology for high school work?" Dr. Barnes said: "I recommend plant physiology as part of the course in botany. It is almost necessary that the teacher of botany know a great deal of physics and chemistry."

To the question, "I want to ask if it would be better to work especially for quantitative results? If we do that, we are limited in part of our experiments," Dr. Barnes replied: "My judgment is that in the elementary course in plant physiology the aim should be mainly qualitative. You will notice that my claim is that plant physiology is in the first rank of the observation sciences. I quite agree that qualitative and quantitative work present different views. I think that botany should be qualitative and observation of physics and chemistry should be quantitative."

Mr. N. A. Harvey, of the Chicago Normal School, made the following remarks: "There are certain difficulties connected with the study of vegetable physiology that seem to me to render it unsuitable for the basis of high school work. Mr. Barnes has stated positively that he would prefer that the teacher should have a good knowledge of physics and chemistry and only a moderate knowledge of botany, rather than that he should have a much more extensive knowledge of botany and little knowledge of physics and chemistry. Yet the teacher is supposed to teach pupils that have no knowledge of physics and chemistry. It seems to me that it is illogical to demand so much of the teacher and still expect the children to derive proper benefit from the subject without at least an elementary knowledge of subjects that constitute the principal preparation for the teacher.

"There is a difficulty in adapting the subject to class work that has not been sufficiently considered. Experiments in physiology take time and they take room. Class work must begin and end on time, according to a program. Experiments in physiology will not do so. It is not likely that we shall ever be able to dispense with a program nor stipulated hours for class work. So physiology in its real sense and class work are somewhat incompatible. This fact is not so bad as it would be if our teaching of botany were necessarily confined to vegetable physiology. My point is

that vegetable physiology should not be made the basis for the work while there are so many other phases of botany that are adapted to class room instruction and we have a large opportunity for selection.

"Most of the experiments in vegetable physiology demand a quantitative treatment for the most effective results. But the thing that we desire children to get from quantitative work can be more easily obtained from physics and chemistry. So I would suggest that there would be an economy of effort in omitting such exercises from botany. This stricture does not apply to those experiments that are not quantitative in character."

Dr. Maxwell said: "If the pupil can see and thoroughly understand the demonstration and is required to write up the results and sketch the apparatus, it is as much of an individual experiment as if he did all the work himself."

Mr. Harvey, in speaking on the subject of "How Much?" said: "There are three ways by which we may measure the amount of a subject to be put into a course: First, by the time that is devoted to it. This is the usual and necessary way, but quite unsatisfactory. Second, by the amount of the subject that is treated—the number of exercises, topics or volumes that are treated. This is less easily stated and scarcely more satisfactory than the other. The third way is by the measure of the amount of good, mental power, that the pupil acquires. Of course, the study is undertaken for the amount of good—power—that the pupil may acquire. The difficulty of measuring the amount of subject to be treated in this way is the difficulty of measuring the amount of good that the pupil gets from it. The other methods are, however, only artificial, and adopted because of the difficulties attending the third measure.

"I believe it will become possible to state a course in a given subject in terms of mental movement. We do not do so now, but we take other things as a measure, assuming more or less definite correspondence between the two, or the three, that does not necessarily exist. I think I could do some good with a class that had only half a year to devote to botany or zoölogy, and I think I have seen classes devote a whole year to the subject without deriving any good from it. If such conditions prevail in two classes, it is better to have a half year that results in some good than a whole year that results in no good.

"Ordinarily I should prefer a whole year in botany or a whole year in zoölogy to half a year in each. It is a matter that depends somewhat upon circumstances other than the subject itself. I believe that a whole year in zoölogy is better under ordinary conditions than half a year in zoölogy and half a year in botany. Also, I would prefer double periods for laboratory work. It has seemed to me that I could obtain about as much work in two consecutive periods as I could from three periods taken singly. There are some disadvantages connected with the double period system that render it unlikely that all schools will soon adopt it. The fact that it does not fit into the program of other subjects is objectionable. Then there is something of a disadvantage in the fact that it is more difficult to keep

pupils up to the highest degree of intensity of work for all the time covered by the longer period.

"The best rule to follow, in the present condition of science teaching, is for every science teacher to get all he can for all scientific subjects and not omit any of them."

Mr. W. R. Mitchell, of the Hyde Park High School, then presented a paper on "The Relation of Biology to Other Sciences in Secondary Schools": "Living things furnish an important part of the phenomena of Nature. Children, like the primitive peoples, seem most in sympathy with the activities and purposes of plants and animals, and therefore by nature all individuals begin with the tendencies of naturalists. However, it is rather evident that until there appears to be purpose in things do we begin to undertake more careful observation.

"There still prevails the rather determined efforts of the elementary schools to change the stress from the delightful kindergarten methods to the often less pleasant 'memory and drill' work, and if the 'twig is bent' as the teacher desires (yet so often broken, in the case of boys), another environment, with much of freedom and spontaneity, may be reached in the secondary school, and then, if the myths and muses of the past have not completely overshadowed the youth, he once more discovers an opportunity to return to his first love, the plants and animals, and in the presence of these and the sympathetic, intelligent naturalist as teacher, he finds the best of all his school work.

"Not many years ago the Huxley method in the study of plants and animals prevailed and the great accumulation of observations of form and structure was utterly burdensome to most students, few of whom survived.

"It was the notion of many who were thoroughly tired of Greek, Latin and mathematics that the observation and tabulation of a large list of plants and animals was very essential to the education of young people in the study of botany and zoölogy, the resulting impression often being inversely as the length of the names, and that it was a great accomplishment 'to think God's thoughts after Him,' in terms, however, of human-made words.

"Such mental discipline was thought to be equivalent to any other. Under such conditions as these a rather prominent educator once said that 'biology has no relation to any other secondary school subject,' and was therefore to be taken as the first science study. It soon began to dawn on many teachers that their subject furnished the opportunity to demonstrate the phenomena of greatest import, namely, the life activities and functions, and suddenly the pendulum swung to physiology. These phenomena to the inquiring mind soon demanded an explanation in terms of morphology, physics and chemics, which were considered to be the tripod of preparation for the study of biology, but the last two studies would not and have not willingly yielded any helpfulness, and so the biologists must themselves give the necessary preparation.

"Again the pendulum has swung and ecology has heralded its mag-

nificent trumpet of interpretation. To many, perhaps not the more conservative teachers, this has appeared to be the grand epitome of biology, the beginning and the ending.

"Will it not be good judgment, however, to remember that our secondary school students are and should be largely in the observational and experimental phase of life, and therefore theories and complete interpretations must be very immature and fundamental?

"The relations of organisms to their environment demand all the nature sciences as a basis for interpretation, but who of us dare ask with any hope of receiving help through the school curriculum.

"Botany students need the language of chemics and physics to explain the essential food elements of plants, also how plants obtain and prepare food; also nutriment distribution through the plant body, food manufacture in green plants, storage and usage; growth and the advantageous direction of roots, stems and leaves. Of geology, students desire knowledge of soils and water supply; of meteorology, air movements (the winds), also moisture, temperature and composition of the air; of astronomy, the quantity and quality of the light; of zoölogy, the devastation by animals needing plant food, also the facts of mutual helpfulness in aiding pollenation and distribution, as well as the relation of favorable hosts in many cases.

"Zoölogy students need important data of chemics and physics as to composition and changes of substances as well as to motion and locomotion; also some reasonable explanation of all the phenomena of nutrition, namely, digestion, absorption, circulation and assimilation; the method of excretion, the maintenance of bodily temperature, excitation, causes and purposes of reproduction. Of geology, they desire knowledge of land and water distribution, including variation in land elevation; of meteorology, data concerning the composition of the air and climatic changes are desirable; of astronomy, variation in amounts of light; of botany, concerning the plant bodies and their products for foods, homes and numerous other economic considerations, including a great variety of medicinal substances.

"It is therefore quite evident that there is a close relation of the biological to other sciences as undertaken in the secondary schools, and it is also quite true that the biological sciences, when so thoroughly undertaken, instead of narrowing one's life, remarkably broadens it.

"Biological knowledge furnishes analogous data in the study and interpretation of sociology, which helps to relate life to the ideals of human society.

"Relatively too few school officials are naturalists by training, therefore the scientific interests of our country, the basis of our prosperity, find entrance to the secondary schools with much difficulty.

"Plants and animals furnish a large source of wealth and commercial interests, therefore their economic and sociological importance are prominently significant and should provide a large source of useful information as well as excellent culture.

"The careful study of biology therefore has no competitor in fundamental importance to every student; its wealth of information and the culture which accompanies its mastery gives it equal or greater rank with other subjects in any course of study for practical, everyday living.

"The fuller and richer interpretation of nature becomes the chief delight of maturer life, and yet the pedagogy of science teaching through the elementary, secondary and higher education must never be ignored by the noble workers in the profession which is our 'high calling'; surely we ought to be the chief exponents of the 'developmental processes' in which we doubtless possess supreme opportunity.

"This may be by and through the materials which we present to our students for study; and finally, many have heard the pleasant statements of appreciation from those with whom they have faithfully worked that such knowledge of living things gives glimpses of the eternal purposes."

Then came a paper by Mr. C. H. Robison, of the Oak Park (Ill.) High School, an abstract of which follows:

"In discussing 'how' to teach botany we have, of late, rather neglected our old friends, the spring flowers, and have lost sight of the fact that the manner of their treatment may also change. While alternation of generation illustrates well the idea of evolution in the lower forms, and also presents difficulties when we deal with higher plants, the gross characters of flowers may be more easily used to illustrate the same theory. The staminate and pistillate cones (catkins) of the willow, one of the first things to appear in the spring, seem to the pupil to be the most natural thing possible if he has just finished pine cones, and their study connects in his mind the two large plant groups in which they are found. Beside the change from the spiral to the whorl arrangement, you will also recall these other changes through which the flower may go as it ascends in the scale of complexity: Reduction in the number of stamens; reduction in number and, finally, the union of pistils; changes in insertion of parts from hypogynous to epigynous, and, in the case of stamens, to epipetalous; union of petals; regularity becoming irregularity; a change of color from the primitive yellow or white through orange to red, and through pink and red to purple and blue. This treatment of flowering plants is especially easy, as the progressive changes correspond fairly well with the advance of the season, and a flower that shows one characteristic of advancement will usually show others. A table made by the pupils from their drawings and descriptions will bring out these points strikingly. Twelve carefully selected types among the dicots will be sufficient to show all of these principles, and may also be used to show group relationships in the case of the crowfoot, rose, borage and composite families."

At the close of the meeting there was a general discussion as to the comparative value of double and single laboratory periods, opinions being very nearly divided.

Reported by Frederic C. Lucas.